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At-home Rice Consumption in Japan —Socio-demographic Analyses

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Abstract

Cereals, potatoes, and beans were the major components of Japanese food diets, accounting for nearly three fourths of total caloric intakes in 1960, when Japan's economy had already recovered completely from the WWII devastation. Rice alone accounted for 48.3% of all foods in terms of caloric intake. The share rapidly declined to 25.9% in 1990, and gradually fell to 22.6% in 2012 during the decades after the economic bubble burst in 1991. Explaining this dietary transition is important to understanding Japan's agriculture and food situation, and may add insights about dietary changes in other countries.

In this article, changes in at-home rice consumption are analyzed from the age/cohort perspectives, i.e., cohort tables, showing individual consumption by age groups for each year from 1980 to 2014 are decomposed, using a Bayesian cohort model; the period effects derived are regressed against economic variables to determine demand elasticities free from the demographic factors; the same cohort tables are decomposed by augmented cohort models to determine economic demand elasticities on top of age, period, and cohort effects in one-step. To supplement the study, a demand system, composed of rice, bread, meat, and fish, is analyzed with an AIDS model, using the period effects estimated for these four commodities individually. Our findings suggest that it may not be easy to attribute steady and drastic decreases in at-home rice consumption to the economic variables—prices of rice and conceivably competitive products, such as bread, meat, and fish, etc.— even after age and cohort effects are accounted for.

JEL 区分：C4, C13, D12

Keywords：at-home consumption, rice, bread, meat, fish, cohort analysis, demand elasticities, demand system, trend

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Introduction

Rice consumption per person in terms of net annual supply of polished rice increased from 105 kg in fiscal year 1955, the year when the government's *1956 White Paper on Economy* proclaimed "mohaya sengo de nai" (the post-war era is over) and peaked at 118 kg in FY 1962. It then gradually and steadily declined to 79 kg in 1980, 68kg in 1995 and 57kg in 2012, respectively (*Food Balance Sheet*).

Japan's Bureau of Statistics has been conducting diary type consumption surveys of approximately 8000 households 12 months annually across the country since 1946 and publishes the survey results in *Monthly and Annual Reports of Family Income and Expenditure Survey (FIES)*. In this article, we will depend mainly on the *FIES Annual Reports* for consumption data.

According to *FIES*, per person household purchases (=consumption, hereafter) of raw rice was 89.1 kg in calendar year 1963, 45.8 kg in 1980, 31.1 kg in 1995, and 24.6 kg in 2013, accounting for 84.8%, 56.0%, 45.7%, and 43.1% of net supply of rice based on *FBS*, respectively. Rice consumption has been shifting away from home preparation of uncooked rice.

As Japan's socio-economy has developed, eating-out, as well as home delivery of sushi and purchasing bentos or cooked rice, either fresh or frozen, at the convenience stores/supermarkets has become increasingly more popular. These developments have resulted in the sharp declines of home cooking of raw rice for the past half century[1)]. However, at-home consumption of rice (i.e., preparation of purchased raw rice at home) remains and will be the most important segment of rice consumption, as will be examined in greater detail later.

Starting in 1979, the *FIES* annual report publishes household purchases (consumption) of various goods and services classified by the age groups of household head (HH). Table 1 provides changes in per person[2)] at-home rice consumption (=raw rice to be prepared at-home, to repeat) during the past 30 years since 1980, classified by the HH age groups. Per person consumption on the grand average (of approximately 8000 households[3)]) steadily decreased from 44.8 kg in 1980 (3 year simple averages of 1979 to 1881) to 26.8 kg in 2010, or by 40.0%. Rice consumption varies by HH age: a

Table 1 Per capita At-home Rice Consumption by HH Age Groups, 1980-2010

(kg/person)

Age Groups	1979～81	1989～91	1999～01	2009～01
＜30	29.5	19.3	15.0	11.5
30－39	35.6	23.0	17.9	15.2
40－49	50.1	35.2	25.6	21.1
50－59	52.7	42.1	34.3	25.7
60＋	53.3	43.7	42.5	36.7
Grand Ave	44.8	35.2	30.2	26.8

Note: ～means simple average of three years.
Sources: *FIES* annual reports, various years.

per person of households with a HH under 30 years of age decreased sharply from 29.5 to 11.5 kg--by 61.0%--whereas that of households with a HH over 60 years of age decreased from 53.3 to 36.7 kg--by 31.0%--over the same period, resulting in even greater disparities between the young and the old in per capita rice consumption at home.

1) "Eating out rates" (total number of eating-out divided by 3 times × days of survey) increased from 11.3% in 1965 to 18.9% in 1990 and slightly declined to 17.1% in 2000, and 18.1% in 2010, according to the *National Nutrition Survey*, 1990, p.46 and 2000, p.44, and 2010, pp.80–91, etc.
2) The ordinary households of 4 persons in size, for example, comprises the household head and his/her spouse of the similar age and two children of different age groups, who may eat more or much less foods than their parents.
3) Single person households are not included.

2. Deriving Individual Consumption of Family Members by Age

When household consumption classified by the age of household head (HH, again) is available, it may be straightforward to estimate individual consumption by age (of HH) by dividing total household consumption by the number of persons contained in the household, as was done in the previous section. This approach could be valid, when one can assume that all members of the family eat nearly the same amount of foods in question as the household head, but this would seldom hold true in everyday lives. In the case of a 4-member family of HH aged 30, for example, 2 members are likely to be small children, who eat substantially less rice than their parents. Dividing total household consumption by 4 would result in substantial underestimates of individual consumption by adult members of the family of HH 30 years of age. In another case of a 4-member family of HH 45 years of age, the children are likely to be both high-teenagers, who normally eat substantially more rice than their parents. A simple division approach is likely to result in more than admissible overestimates of individual consumption by those in their mid-forties.

Mori and Inaba (1997) explicitly incorporated age structures of households classified by HH age groups into a (behavioral) equation system (Prais, 1953; Morishima, 1984) to estimate individual consumption by household members by age groups, with a few constraints of plausible assumptions, such as that individual consumption in the mid-forties should be equal to that in the early fifties, for example. Tanaka, Mori, and Inaba refined the model statistically later, replacing the equality constraints by the more natural constraints of "gradual changes between successive age groups"[4] in individual consumption (Tanaka, Mori, and Inaba, 2004).

The Tanaka, Mori, and Inaba (TMI) model is summarized as below:

$H_j - \Sigma C_{ij} X_i = E_j$ (i = 1–16; j = 1–10) (1)

$X_k - X_{k+1} = E_k$ (k = 1–15) (2)

where

H_j : consumption by household headed by someone j years of age
C_{ij} : number of individuals of i years of age in household headed by someone j years of age
X_i : estimated consumption by individuals of i years of age
E_j, E_k : residuals

X_i, individual consumption by i years of age, is estimated by minimizing the sum of squared residuals (1) and (2) above.

Table 2 provides estimates of individual annual at-home consumption of (raw) rice by 5 year age bracket up to the oldest category, 75+years of age, for the period of 1980–2014. The two youngest groups, 0–4 and 5–9 years of age, do not represent any sizable segments of household age structures classified by HH age groups. Judging from t values, etc., the consumption estimates for these age groups are not as stable as the older ones and not provided in Table 2.

A brief comparison of these data derived on individual consumption by age of household members by the TMI model in Table 2 to the data for household consumption by HH age groups simply divided by the household size in Table 1 confirms the discussion in the preceding section: older people in their 50s and 60s consume appreciably more rice than the younger ones in their 20s and 30s; further-more, the younger generations (birth cohorts) seem to consume appreciably less (home-cooked) rice than the older ones.

4) Certain disparities are explicitly assumed between the youngest age groups: between 0–4 and 5–9, and 5–9 and 10–14 years old, based on the nutrient intakes data, the *National Nutrition Survey*, various issues.

3. Decomposing Cohort Table into Age, Period, and Cohort Effects

When the general cohort table, comprising 12 age groups from the high-teenage years, 15–19, to the elderly years, 70–74, is decomposed into age/period/cohort effects by means of the Nakamura's Bayesian cohort model (Nakamura, 1986), subject to the usual sum to zero constraints, we come up with the statistical results shown in Table 3. The three youngest age groups of 0–4, 5–9, and 10–14 years old are deleted, on the unproven premise that the eating habits of foods in general are firmly formed in the late teenage years (Ohga, 1999; Mori and Saegusa, 2010). The cells of the oldest age group, 75 and older, are also deleted, because they contain more than one age group, 75–79, consequently more than one birth cohort in each cell. The age cell, over 75 in 1980, for example, contains the cohort born in 1901 to 1905, the cohort born in 1896 to 1900, and so on, whereas the age cell of 70–74 years old in 1980 contains only one cohort, born in 1906 to 1910.

There are no theoretical solutions to overcome "the identification problem" inherent in A/P/C cohort analysis arising from the linear dependency of three variables, i.e.: $t=i+k$, where t denotes the survey period, i age in years old, and k the period in which the subject was born (Mason and Fienberg, 1985; Yang, Fn, and Land., 2004; etc.). We attempt to practically overcome the identification problem by applying the Bayesian approach proposed by Nakamura as the main analytical

Table 2　Individual At-home Consumption of Rice by Age Groups, 1980 to 2014

Age/Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
10～14	43.27	41.11	38.70	34.92	37.14	34.22	32.81	30.75	27.94	25.06	22.59	22.03	23.38	22.42	17.36	17.14	18.25	15.31
15～19	50.93	49.30	46.51	41.84	45.19	41.20	42.32	38.91	34.80	30.84	28.74	28.56	29.58	28.82	22.96	23.06	23.63	20.63
20～24	38.60	37.30	36.05	32.97	35.55	32.19	34.26	30.52	27.67	25.26	24.74	24.56	25.78	24.79	20.19	21.14	20.83	18.51
25～29	35.07	33.15	33.06	30.47	31.96	28.68	31.00	28.21	25.69	23.30	23.53	23.50	24.71	23.71	19.55	21.28	20.86	19.23
30～34	40.65	40.73	38.34	37.49	36.64	34.71	34.26	31.57	28.16	27.80	27.21	26.92	25.49	24.91	22.44	22.53	21.84	22.18
35～39	49.20	48.67	46.68	46.23	44.80	44.69	40.70	38.65	36.45	37.25	34.44	33.62	32.79	31.67	28.11	27.67	27.33	27.88
40～44	58.73	57.43	55.34	56.32	55.54	55.14	50.91	49.66	46.69	47.07	44.06	43.14	39.42	41.15	37.73	34.54	34.39	32.71
45～49	61.16	62.35	59.50	60.36	60.44	60.14	59.89	56.05	51.11	51.33	49.42	49.59	44.08	46.93	43.51	41.10	40.17	41.15
50～54	59.83	61.55	59.69	62.30	59.57	59.71	58.54	56.51	53.48	54.29	52.25	51.15	48.08	50.10	48.17	45.71	43.26	43.86
55～59	60.60	58.63	59.45	61.41	58.85	59.80	58.39	58.23	55.11	55.22	53.88	53.79	48.70	52.29	49.00	47.74	46.77	47.26
60～64	62.02	59.68	58.21	63.98	57.24	59.55	59.42	57.36	53.78	53.73	53.57	51.96	48.93	51.54	48.48	46.56	48.66	51.56
65～69	60.47	59.02	60.91	64.20	57.36	59.35	58.85	54.93	50.19	51.20	51.95	50.53	51.82	52.44	47.37	47.36	49.05	49.19
70～74	54.62	53.76	56.79	58.79	52.60	54.26	53.68	49.34	44.51	45.90	46.94	45.76	48.49	48.42	43.02	43.73	44.99	43.94
75～	47.47	46.93	49.94	51.42	46.05	47.43	46.94	42.93	38.55	39.89	40.90	39.93	42.85	42.60	37.68	38.54	39.43	38.07

(kg/person)

Age/Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
10～14	16.49	14.00	15.15	16.30	14.97	13.10	12.09	13.32	12.98	13.96	11.60	12.04	14.42	12.72	13.37	13.81	12.43
15～19	20.78	16.61	18.16	20.21	18.01	15.98	15.37	15.75	16.23	17.35	14.60	14.45	17.51	15.38	15.94	16.09	14.19
20～24	18.80	14.57	16.76	17.94	15.86	14.99	14.68	13.96	13.98	15.01	12.90	11.97	14.36	13.19	13.03	12.95	10.85
25～29	19.39	16.30	19.24	19.08	17.54	17.52	17.11	16.01	15.17	16.25	14.74	13.10	14.75	14.73	13.61	13.65	10.63
30～34	21.96	21.01	21.84	20.84	21.18	20.96	19.94	19.47	18.77	18.73	19.29	18.42	17.13	18.42	16.52	16.09	13.60
35～39	24.76	26.90	28.09	25.83	25.49	24.74	22.99	23.23	22.85	22.00	23.70	23.59	21.28	21.85	20.35	19.56	18.29
40～44	34.06	33.81	33.31	30.90	30.32	29.02	26.53	27.21	27.02	25.67	27.62	27.79	26.49	24.56	24.30	23.36	23.61
45～49	40.80	38.30	36.83	36.96	34.78	33.48	31.57	30.66	30.57	28.80	31.35	30.73	29.50	26.79	26.49	24.71	25.71
50～54	42.29	43.80	43.58	41.08	39.05	38.34	37.49	34.14	33.74	31.65	35.17	33.03	30.99	29.04	27.63	24.78	25.65
55～59	47.93	49.31	49.07	45.54	43.57	44.15	41.71	39.58	37.36	35.19	39.78	36.92	34.09	32.96	30.61	28.36	28.19
60～64	50.04	52.17	51.39	46.27	47.88	49.87	44.76	45.69	41.22	39.60	44.79	42.06	38.89	38.31	35.60	35.01	33.34
65～69	49.75	51.67	50.68	48.69	50.42	52.32	47.69	48.69	44.06	44.23	48.11	45.64	43.35	42.44	40.58	39.45	37.78
70～74	45.43	46.85	45.81	45.55	46.86	47.69	45.65	44.86	41.66	43.93	45.32	43.29	42.63	41.02	40.70	37.87	38.32
75～	39.71	40.87	39.91	40.28	41.25	41.57	40.85	39.23	37.00	39.94	40.17	38.44	38.50	36.75	37.07	33.68	35.13

Notes： Two youngest groups, 0～4 and 5～9 are not provided in the table.
Sources： Calculated by Mori, using *FIES*, classified by HH age groups.

tool (Nakamura, 1986), with several technical modifications, as needed (Mori, Saegusa, and Dyck, 2012; Mori, Saegusa, and Inaba, 2014; etc.).

The basic structure of the model is summarized below:

In the ordinary cohort modeling, X_{it}, the action by i year-olds at the period t, is commonly expressed as follows, which may be "a poor approximation of how social change occurs" (Yang et al., 2008, p.1733), without any deductive theories like utility maximization in microeconomics, for example.

$$X_{it} = B + A_i + P_t + C_k + \varepsilon_{it} \qquad (3)$$

where:

X_{it}: event (average consumption) by i year-olds at the time, t

B: grand mean effect

A_i: the effect to be attributed to age, i years old

P_t: the effect to be attributed to period, t

C_k: the effect to be attributed to (birth) cohort (k)

ε_{it}: random errors

To center the parameters, we set the usual sum to zero constraints.

$$\Sigma_i A_i = \Sigma_t P_t = \Sigma_k C_k = 0 \qquad (4)$$

The model (3) can be written in the conventional matrix form of a least-squares regression below.

$$Y = Xb + \varepsilon \qquad (5)$$

$$\sum_i \sum_t [X_{it} - (B + A_i + P_t + C_k)]^2 = \min! \qquad (6)$$

To overcome, or tackle with the identification problem stated above, one of the easiest measures taken by the conventional generalized models is to impose equality constraints on neighboring age and/or period groups (Yang, Fu, and Land, 2004, p.81). Nakamura imposes intuitively more natural assumptions of "gradual changes between successive parameters" for all three factors of age, period, and cohort effects and minimizes the following equation, allotting the hyper-parameters determined on the objective principle of **ABIC** (Akaike's Bayesian Information Criterion) minimization.

$$\frac{1}{\sigma_A^2}\Sigma(A_i - A_{i+1})^2 + \frac{1}{\sigma_P^2}\Sigma(P_t - P_{t+1})^2 + \frac{1}{\sigma_C^2}\Sigma(C_k - C_{k+1})^2 = \min! \qquad (7)$$

Table 3 demonstrates that age effects on rice consumption of individual consumers in their 50s, 60s, and the early 70s are distinctly positive, whereas age effects of younger adults under 40 years of age are clearly negative (under the sum to zero constraints, (4) above). Cohort effects are distinctly positive for the older generations born before the mid-1950s, while for those born after the mid-1950s, cohort effects are increasingly negative, as large as −11.0kg, against the grand mean effect of 36.1kg for those born after the mid-1980s, for example. The period effects, provided in the middle column, suggest that individual rice consumption, after the age and cohort effects accounted for, has been steadily declining from the outset of the earlier 1980s.[5] The period effects thus determined could reflect changes in prices and household income, and other unknown forces, including unspecified "structural changes"(Huang and Bouis, 2001; Mori, 2015; etc.).

In subsequent regressions, the double-log form is used for easier visual comprehensions. The co-

Table 3 Individual At-home Rice Cosumption by Age Decomposed into Age, Period, and Cohort Effects, 1980-2014, Bayesian Model

Grand Mean Effects = 36.081 (.151) (kg/person)

Age Efects Age yrs		(SE)
15–19	− 1.942	2.28
20–24	− 7.290	1.89
25–29	− 8.891	1.48
30–34	− 7.099	1.08
35–39	− 3.296	0.70
40–44	1.426	0.38
45–49	3.845	0.38
50–54	4.233	0.70
55–59	4.983	1.08
60–64	5.692	1.48
65–69	6.001	1.89
70–74	2.336	9.83
(Sum)	− 0.002	

Note : Figure in parentheses denotes standard errors.

Period Effects Year		(SE)
1980	11.590	1.47
1981	11.027	1.39
1982	10.453	1.32
1983	10.622	1.24
1984	9.514	1.17
1985	8.999	1.09
1986	8.282	1.02
1987	6.041	0.95
1988	3.319	0.87
1989	2.644	0.81
1990	1.905	0.74
1991	1.387	0.68
1992	0.621	0.62
1993	0.746	0.57
1994	− 1.794	0.52
1995	− 2.462	0.49
1996	− 2.413	0.47
1997	− 2.408	0.46
1998	− 2.336	0.47
1999	− 2.346	0.49
2000	− 2.038	0.52
2001	− 2.716	0.57
2002	− 3.070	0.62
2003	− 3.203	0.68
2004	− 4.397	0.74
2005	− 4.813	0.81
2006	− 5.554	0.87
2007	− 5.463	0.95
2008	− 4.220	1.02
2009	− 4.777	1.09
2010	− 5.288	1.17
2011	− 5.932	1.24
2012	− 6.655	1.32
2013	− 7.369	1.39
2014	− 7.898	1.47
(Sum)	− 0.002	

Source : Estimated by Mori.

Cohort Effects Born		(SE)
1906～10	5.673	3.79
1911～15	6.649	3.39
1916～20	6.863	2.96
1921～25	7.668	2.54
1926～30	9.017	2.13
1931～35	10.298	1.72
1936～40	10.362	1.32
1941～45	8.089	0.93
1946～50	4.137	0.60
1951～55	− 0.236	0.43
1956～60	− 3.842	0.59
1961～65	− 4.482	0.93
1966～70	− 4.239	1.31
1971～75	− 5.341	1.71
1976～80	− 6.983	2.12
1981～85	− 9.389	2.53
1986～90	− 10.875	2.95
1991～95	− 11.733	3.38
1996～	− 11.639	3.76
(Sum)	− 0.003	

Table 4 Individual At-home Rice Consumption by Age Decomposed into Age, Period, and Cohort Effects in Logs, 1980-2014, Bayesian Model

Grand Mean Effects = 3.45 (.004) (in natural logs)

Age Efects Age yrs		(SE)
15–19	0.081	0.078
20–24	−0.174	0.064
25–29	−0.263	0.050
30–34	−0.209	0.037
35–39	−0.094	0.023
40–44	0.026	0.011
45–49	0.076	0.011
50–54	0.082	0.023
55–59	0.104	0.037
60–64	0.132	0.050
65–69	0.152	0.064
70–74	0.088	0.336
(Sum)	0.001	

Note : The same as Table 3.

Period Effects Year		(SE)
1980	0.267	0.049
1981	0.256	0.047
1982	0.243	0.044
1983	0.240	0.042
1984	0.225	0.039
1985	0.211	0.036
1986	0.199	0.034
1987	0.150	0.031
1988	0.088	0.028
1989	0.066	0.026
1990	0.049	0.023
1991	0.041	0.021
1992	0.028	0.019
1993	0.025	0.017
1994	−0.047	0.015
1995	−0.058	0.014
1996	−0.056	0.013
1997	−0.062	0.013
1998	−0.062	0.013
1999	−0.077	0.014
2000	−0.052	0.015
2001	−0.057	0.017
2002	−0.071	0.019
2003	−0.081	0.021
2004	−0.111	0.023
2005	−0.120	0.026
2006	−0.132	0.028
2007	−0.122	0.031
2008	−0.095	0.034
2009	−0.110	0.036
2010	−0.108	0.039
2011	−0.127	0.042
2012	−0.151	0.044
2013	−0.177	0.047
2014	−0.213	0.049
(Sum)	−0.001	

Cohort Effects Born		(SE)
1906～10	0.212	0.130
1911～15	0.237	0.116
1916～20	0.246	0.101
1921～25	0.282	0.087
1926～30	0.325	0.072
1931～35	0.361	0.058
1936～40	0.367	0.044
1941～45	0.331	0.031
1946～50	0.258	0.019
1951～55	0.152	0.012
1956～60	0.035	0.019
1961～65	−0.027	0.031
1966～70	−0.067	0.044
1971～75	−0.147	0.058
1976～80	−0.273	0.072
1981～85	−0.448	0.086
1986～90	−0.583	0.101
1991～95	−0.640	0.115
1996～	−0.621	0.129
(Sum)	0.000	

Source : Estimated by Mori.

hort table, Table 2, is decomposed in natural logs to produce Table 4, which is essentially the same as Table 3. The age effects are clearly positive for the older age groups and the newer generations are shown to carry steadily declining cohort effects, so forth. The period effects provided in Table 4, estimated in natural logs are regressed against the prices of rice, bread, fish, meat, and vegetables and household living expenditures per adult equivalence scale as a proxy for income (OECD, 1982), all deflated by the CPI for all goods and services, resulting in equation (8). The own price elasticity of rice at 0.24 does not seem economically reasonable; cross-price elasticities of bread and meat are 0.38 and 0.64, respectively; those of fish and vegetables, both of which carry negative signs should be neglected because the coefficients lack statistical significance; income elasticity at −0.95 may or may not be reasonable but should not be neglected.

$$\begin{aligned}(gm+pe) = {} & \underset{(4.53)}{4.90} + \underset{(3.69)}{0.24}\ln(\text{p-rice}) + \underset{(2.69)}{0.38}\ln(\text{p-bread}) + \underset{(4.96)}{0.64}\ln(\text{p-meat}) - \underset{(2.12)}{0.38}\ln(\text{p-fish}) \\ & - \underset{(1.27)}{0.23}(\text{p-vege}) - \underset{(4.55)}{0.95}\ln(ex/ae) \qquad \text{Adj.}R^2 = 0.97 \qquad (8)\end{aligned}$$

When prices of fish and vegetables are deleted, we come up with the similar outcomes, as shown below in (9).

$$(gm+pe) = \underset{(4.76)}{5.50} + \underset{(3.31)}{0.24}\ln(\text{p-rice}) + \underset{(1.69)}{0.20}\ln(\text{p-bread}) + \underset{(3.88)}{0.43}\ln(\text{p-meat}) - \underset{(6.07)}{1.19}\ln(ex/ae) \qquad \text{Adj.}R^2 = 0.96 \qquad (9)$$

Figures in parentheses in the equations above denote t values.

Considering that a drastic decline in at-home rice consumption in the past half century may have been affected by unidentified factors other than the economic variables of prices and income and the demographic effects, we may need further exploration for changes in rice consumption.

Tables 5, 6, and 7[6)] provide the cohort parameters in logs for at-home bread, meat and fish consumption, respectively, estimated in the same fashions as for rice presented in Table 4. The period effects for consumption of bread, meat, and fish, respectively for 35 years from 1980 to 2014 are regressed against prices of four or five presumably related products, rice, bread, meat, fish, and vegetables and per adult household expenditures, as conducted for rice above. Table 8 summarizes the economic demand elasticities for rice, bread, meat, and fish, estimated in this "two-step approach": first to identify period effects from 1980 to 2014, controlling for age and cohort effects, and then to regress the period effects (+ grand mean effect) for the specific product against the prices of related products and household incomes.

To repeat, the own price elasticity of rice is estimated at +0.24, while the cross price elasticities of bread and meat are estimated at +0.20 and +0.43, respectively with reasonable statistical significance and (per adult household) expenditure elasticity at −1.19 with high t-value, with the model adjusted R^2 at 0.96. Intuitively, the positive own price elasticity along with a very high negative expenditure elasticity should be questioned and may need further scrutiny. On the other hand, the equation for bread showed the expected negative sign in its own price elasticity at −1.05 (8.93) and the own price elasticities of both meat and fish are estimated at −0.67 (4.98) and −0.77 (4.52), respectively (numbers in parentheses = t values). The expenditure elasticity for meat, however, turned out highly negative at −1.11 (6.07), as compared to 0.74 (3.31) in expenditure elasticity for

Table 5 Individual At-home Bread Consumption by Age Decomposed into Age, Period, and Cohort Effects in Logs, 1980-2014, Bayesian Model

Grand Mean Effects = 2.464 (.003) (in natural logs)

Age Efects Age yrs		(SE)
15–19	0.148	0.058
20–24	− 0.068	0.048
25–29	− 0.112	0.037
30–34	− 0.054	0.027
35–39	− 0.034	0.017
40–44	− 0.020	0.008
45–49	− 0.043	0.008
50–54	− 0.074	0.017
55–59	− 0.036	0.027
60–64	0.054	0.037
65–69	0.126	0.048
70–74	0.114	0.250
(Sum)	0.001	

Note : The same as Table 3.

Period Effects Year		(SE)
1980	− 0.086	0.037
1981	− 0.076	0.035
1982	− 0.084	0.033
1983	− 0.075	0.031
1984	− 0.098	0.029
1985	− 0.121	0.027
1986	− 0.129	0.025
1987	− 0.149	0.023
1988	− 0.156	0.021
1989	− 0.117	0.020
1990	− 0.115	0.018
1991	− 0.102	0.016
1992	− 0.098	0.015
1993	− 0.071	0.013
1994	− 0.061	0.012
1995	− 0.081	0.011
1996	− 0.069	0.010
1997	− 0.068	0.010
1998	− 0.058	0.010
1999	− 0.029	0.011
2000	− 0.036	0.012
2001	− 0.046	0.013
2002	0.097	0.015
2003	0.133	0.016
2004	0.158	0.018
2005	0.128	0.020
2006	0.143	0.021
2007	0.148	0.023
2008	0.137	0.025
2009	0.158	0.027
2010	0.164	0.029
2011	0.167	0.031
2012	0.158	0.033
2013	0.164	0.035
2014	0.169	0.037
(Sum)	− 0.001	

Source : Estimated by Mori.

Cohort Effects Born		(SE)
1906〜10	− 0.289	0.096
1911〜15	− 0.166	0.086
1916〜20	− 0.109	0.075
1921〜25	− 0.074	0.064
1926〜30	− 0.053	0.054
1931〜35	− 0.031	0.043
1936〜40	0.026	0.033
1941〜45	0.077	0.023
1946〜50	0.123	0.014
1951〜55	0.139	0.009
1956〜60	0.140	0.014
1961〜65	0.138	0.023
1966〜70	0.132	0.033
1971〜75	0.117	0.043
1976〜80	0.084	0.053
1981〜85	0.016	0.064
1986〜90	− 0.032	0.075
1991〜95	− 0.099	0.085
1996〜	− 0.140	0.095
(Sum)	− 0.001	

Table 6 Individual At-home Meat Consumption by Age Decomposed into Age, Period, and Cohort Effects in Logs, 1980-2014, Bayesian Model

Grand Mean Effects = 2.565 (.002) (in natural logs)

Age Efects Age yrs		(SE)	Period Effects Year		(SE)	Cohort Effects Born		(SE)
15–19	0.184	0.042	1980	−0.004	0.026	1906〜10	−0.185	0.069
20–24	−0.020	0.035	1981	−0.021	0.025	1911〜15	−0.198	0.062
25–29	−0.069	0.027	1982	−0.009	0.024	1916〜20	−0.178	0.054
30–34	−0.073	0.020	1983	−0.040	0.022	1921〜25	−0.141	0.046
35–39	−0.040	0.012	1984	−0.031	0.021	1926〜30	−0.072	0.039
40–44	0.029	0.006	1985	−0.019	0.019	1931〜35	−0.019	0.031
45–49	0.069	0.006	1986	−0.011	0.018	1936〜40	0.029	0.024
50–54	0.065	0.012	1987	−0.010	0.017	1941〜45	0.084	0.016
55 − 59	0.044	0.020	1988	−0.033	0.015	1946〜50	0.098	0.010
60–64	0.028	0.027	1989	−0.030	0.014	1951〜55	0.076	0.006
65–69	−0.052	0.035	1990	−0.034	0.012	1956〜60	0.045	0.009
70–74	−0.164	0.181	1991	−0.031	0.011	1961〜65	0.049	0.016
(Sum)	0.001		1992	−0.029	0.010	1966〜70	0.089	0.024
			1993	−0.011	0.009	1971〜75	0.117	0.031
			1994	−0.011	0.008	1976〜80	0.105	0.039
			1995	−0.007	0.007	1981〜85	0.066	0.046
			1996	−0.022	0.006	1986〜90	0.021	0.054
			1997	−0.018	0.006	1991〜95	0.005	0.062
			1998	−0.026	0.006	1996〜	0.008	0.069
			1999	−0.013	0.007	(Sum)	−0.001	
			2000	−0.014	0.008			
			2001	−0.048	0.009			
			2002	−0.032	0.010			
			2003	−0.042	0.011			
			2004	−0.048	0.012			
			2005	−0.020	0.014			
			2006	−0.016	0.015			
			2007	0.005	0.017			
			2008	0.030	0.018			
			2009	0.070	0.019			
			2010	0.073	0.021			
			2011	0.081	0.022			
			2012	0.097	0.024			
			2013	0.135	0.025			
			2014	0.138	0.026			
			(Sum)	−0.001				

Note : The same as Table 3.

Source : Estimated by Mori.

Table 7 Individual At-home Fish Consumption by Age Decomposed into Age, Period, and Cohort Effects in Logs, 1980-2014, Bayesian Model

Grand Mean Effects＝2.371（.004） （in natural logs）

Age Efects Age yrs		(SE)
15–19	−0.060	0.062
20–24	−0.106	0.051
25–29	−0.169	0.040
30–34	−0.122	0.029
35–39	−0.079	0.019
40–44	−0.027	0.011
45–49	0.039	0.011
50–54	0.100	0.019
55–59	0.132	0.029
60–64	0.135	0.040
65–69	0.108	0.051
70–74	0.049	0.266
(Sum)	0.000	

Note : The same as Table 3.

Period Effects Year		(SE)
1980	0.013	0.039
1981	0.000	0.037
1982	−0.013	0.035
1983	0.004	0.035
1984	0.011	0.031
1985	0.006	0.029
1986	0.003	0.027
1987	−0.019	0.025
1988	−0.025	0.023
1989	−0.021	0.021
1990	−0.031	0.019
1991	−0.015	0.017
1992	0.029	0.016
1993	0.042	0.014
1994	0.039	0.013
1995	0.038	0.012
1996	0.020	0.011
1997	0.022	0.011
1998	0.022	0.011
1999	0.016	0.012
2000	0.019	0.013
2001	0.035	0.014
2002	0.061	0.016
2003	0.049	0.018
2004	0.044	0.019
2005	0.039	0.021
2006	0.023	0.023
2007	0.017	0.025
2008	0.009	0.027
2009	−0.006	0.029
2010	−0.049	0.031
2011	−0.078	0.033
2012	−0.099	0.035
2013	−0.097	0.037
2014	−0.108	0.039
(Sum)	0.000	

Source : Estimated by Mori.

Cohort Effects Born		(SE)
1906～10	0.409	0.108
1911～15	0.461	0.093
1916～20	0.472	0.080
1921～25	0.483	0.069
1926～30	0.483	0.058
1931～35	0.466	0.047
1936～40	0.466	0.036
1941～45	0.460	0.025
1946～50	0.405	0.017
1951～55	0.289	0.012
1956～60	0.136	0.016
1961～65	−0.020	0.025
1966～70	−0.138	0.036
1971～75	−0.247	0.046
1976～80	−0.404	0.057
1981～85	−0.609	0.069
1986～90	−0.843	0.080
1991～95	−1.106	0.092
1996～	−1.164	0.105
(Sum)	−0.001	

Table 8 Demand Elasticities Summary, Rice, Bread, Meat, and Fish, Using Period Effects Identified by Bayesian Cohort Analysis

	Constant	P_rice	P_bread	P_meat	P_fish	P_vege	Exp/ae	Adj. R^2
Rice	5.50	0.24	0.20	0.43			−1.19	
	(4.76)	(3.31)	(1.69)	(3.89)			(6.07)	0.96
Bread	10.42		−1.05	−0.56		0.27	−0.33	
	(10.88)		(8.93)	(7.80)		(2.32)	(1.50)	0.94
Meat	8.27			−0.67	0.51	0.20	−1.11	
	(7.62)			(4.98)	(2.82)	(1.42)	(6.07)	0.51
Fish	−0.25	0.14		0.45	−0.77		0.74	
	(0.18)	(1.74)		(2.83)	(4.52)		(3.31)	0.41

Notes : All prices and expenditures deflated by CPI (2010＝100) ; figures in parentheses denote t-values.
The prices which showed t-values smaller than 1 in absolute value not used.
Sources : Calculated by Mori, using the data provided in Tables 4, 5, 6, and 7.

fish.

5) The authors also decomposed the same cohort table, Table 2, by means of the “intrinsic estimator” (IE) developed by Yang et al. (2004 and 2008), to produce cohort parameters very similar to those estimated by the Nakamura’s Bayesian model. The IE results are provided in Appendix Table 1.

6) Cohort tables comprising individual consumption by age groups for 35 years from 1980 to 2014 for bread, meat, and fish are provided in Appendix Tables 2, 3, and 4.

4. Determining Cohort Parameters and Economic Demand Elasticities in One -Step by Augmented Cohort Models

In micro-economics, demand for a chosen product is determined by its own price and prices of other related products and by the incomes of those who demand the product and more often than not by changes in social circumstances, such as increases in health-consciousness (B-W Lin et al., 2003), “westernization” in diet (Tokoyama and Egaitsu, 1994), etc. R. Schrimper raised a question on Salathe’s presentation at the American Agricultural Association Meeting, 1979, “The Effect of Changes in Population Characteristics on Food Consumption” (Salathe, 1979), asking that “is it reasonable to expect all generations to follow the same transformation of eating habits over the life cycle?” He suggested that “cohort effects as opposed to pure age effects” should not be overlooked (Schrimper, 1979, p. 1059). Stimulated by his insightful comments, we have been trying to incorporate age/cohort effects into food demand analyses for some time since the early 2000s (Mori eds., 2001).

If one’s consumption of a certain food is determined explicitly by the economic factors such as prices and incomes on top of demographic factors of age/cohort effects, it should be theoretically desirable to determine the impacts of economic and demographic variables simultaneously in one-step. This is what Stewart and Blisard proposed (2008) and Saegusa et al. have been following suits

Table 9 At-home Rice Consumption by Age Decomposed into Age/Period/Cohort Effects, 1980-2014
Augmented BE Model in Logs
Own Price Elasticity of Rice＝.01（.12）
Cross Price Elasticity of Bread＝.16（.23）; Cross Price Elasticity of Meat＝.34（.23）
Cross Price Elasticity of Fish＝－.30（.25）; Income Elasticity＝－.72（.41）

Grand Mean Effect＝6.061（2.437） **ABIC**＝－1120.921 （in natural logs）

Age Effects Years Old		(SE)
15–17	0.039	0.046
20–24	－0.208	0.046
25–29	－0.290	0.048
30–34	－0.229	0.050
35–39	－0.105	0.055
40–44	0.022	0.061
45–49	0.080	0.061
50–54	0.093	0.055
55–59	0.123	0.050
60–64	0.158	0.048
65–69	0.186	0.046
70–74	0.130	0.046
(Sum)	－0.001	

Note: Figures in parentheses denote standard errors in absolute value.

Period Effects Annual Year		(SE)
1980	0.155	0.054
1981	0.146	0.049
1982	0.153	0.048
1983	0.148	0.047
1984	0.139	0.047
1985	0.142	0.049
1986	0.145	0.048
1987	0.122	0.049
1988	0.082	0.047
1989	0.069	0.048
1990	0.068	0.047
1991	0.072	0.048
1992	0.067	0.047
1993	0.069	0.044
1994	0.003	0.047
1995	－0.009	0.046
1996	－0.004	0.045
1997	－0.019	0.047
1998	－0.024	0.048
1999	－0.042	0.046
2000	－0.024	0.042
2001	－0.032	0.040
2002	－0.039	0.043
2003	－0.059	0.040
2004	－0.095	0.041
2005	－0.105	0.042
2006	－0.120	0.045
2007	－0.109	0.046
2008	－0.102	0.046
2009	－0.111	0.048
2010	－0.096	0.048
2011	－0.120	0.046
2012	－0.129	0.050
2013	－0.146	0.054
2014	－0.195	0.055
(Sum)	0.000	

Source: Estimated by Mori.

Cohort Effects Born in		(SE)
1906～10	0.145	0.087
1911～15	0.175	0.089
1916～20	0.193	0.090
1921～25	0.236	0.090
1926～30	0.287	0.088
1931～35	0.330	0.082
1936～40	0.344	0.076
1941～45	0.316	0.070
1946～50	0.250	0.068
1951～55	0.152	0.068
1956～60	0.043	0.068
1961～65	－0.012	0.070
1966～70	－0.044	0.078
1971～75	－0.116	0.082
1976～80	－0.235	0.088
1981～85	－0.402	0.090
1986～90	－0.529	0.090
1991～95	－0.579	0.089
1996～	－0.554	0.088
(Sum)	0.000	

Table 10 At-home Bread Consumption by Age Decomposed into Age/Period/Cohort Effects, 1980-2014
Augmented BE Model in Logs
Own Price Elasticity of Bread＝−0.97（.17）
Cross Price Elasticity of Rice＝.07（.09）; Cross Price Elasticity of Meat＝.13（.17）
Cross Price Elasticity of Fish＝−.15（.18）; Income Elasticity＝.15（.30）

Grand Mean Effect＝5.984（1.781） **ABIC**＝−1378.559 （in natural logs）

Age Effects Years Old		(SE)	Period Effects Annual Year		(SE)	Cohort Effects Born in		(SE)
15–17	0.097	0.032	1980	−0.098	0.040	1906～10	−0.374	0.062
20–24	−0.110	0.033	1981	−0.087	0.035	1911～15	−0.239	0.063
25–29	−0.144	0.034	1982	−0.083	0.035	1916～20	−0.174	0.064
30–34	−0.077	0.036	1983	−0.074	0.035	1921～25	−0.129	0.064
35–39	−0.048	0.039	1984	−0.089	0.035	1926～30	−0.099	0.062
40–44	−0.025	0.044	1985	−0.096	0.036	1931～35	−0.068	0.058
45–49	−0.039	0.044	1986	−0.091	0.035	1936～40	−0.002	0.054
50–54	−0.060	0.039	1987	−0.097	0.036	1941～45	0.059	0.050
55–59	−0.013	0.036	1988	−0.105	0.034	1946～50	0.114	0.048
60–64	0.087	0.034	1989	−0.066	0.035	1951～55	0.139	0.048
65–69	0.167	0.033	1990	−0.051	0.035	1956～60	0.149	0.048
70–74	0.165	0.032	1991	−0.032	0.035	1961～65	0.157	0.050
(Sum)	0.000		1992	−0.030	0.034	1966～70	0.160	0.055
			1993	−0.020	0.032	1971～75	0.155	0.058
			1994	−0.011	0.034	1976～80	0.131	0.062
			1995	−0.008	0.034	1981～85	0.072	0.064
			1996	0.009	0.032	1986～90	0.033	0.064
			1997	0.015	0.034	1991～95	−0.024	0.063
			1998	0.022	0.035	1996～	−0.059	0.062
			1999	0.037	0.034	(Sum)	0.001	
			2000	0.023	0.030			
			2001	0.003	0.029			
			2002	0.028	0.031			
			2003	0.034	0.029			
			2004	0.040	0.030			
			2005	0.019	0.031			
			2006	0.035	0.033			
			2007	0.046	0.033			
			2008	0.068	0.034			
			2009	0.098	0.035			
			2010	0.103	0.035			
			2011	0.115	0.034			
			2012	0.113	0.036			
			2013	0.107	0.039			
			2014	0.124	0.040			
			(Sum)	0.001				

Note: Figures in parentheses denote standard errors in absolute value.

Source: The same as Table 9.

Table 11 At-home Meat Consumption by Age Decomposed into Age/Period/Cohort Effects, 1980-2014
Augmented BE Model in Logs
Own Price Elasticity of Meat＝－.22(.14)
Cross Price Elasticity of Fish＝.22(.16); Cross Price Elasticity of Bread＝－.11(.15)
Cross Price Elasticity of Veges＝－.15(.07); Income Elasticity＝.05(.26)

Grand Mean Effect＝3.498(1.572) **ABIC**＝－1736.379 (in natural logs)

Age Effects Years Old		(SE)	Period Effects Annual Year		(SE)	Cohort Effects Born in		(SE)
15–17	0.195	0.024	1980	0.025	0.028	1906～10	－0.168	0.046
20–24	－0.011	0.024	1981	0.006	0.026	1911～15	－0.182	0.046
25–29	－0.062	0.025	1982	0.001	0.026	1916～20	－0.165	0.047
30–34	－0.068	0.026	1983	－0.014	0.024	1921～25	－0.129	0.047
35–39	－0.037	0.029	1984	－0.004	0.023	1926～30	－0.062	0.046
40–44	0.030	0.032	1985	－0.004	0.027	1931～35	－0.011	0.043
45–49	0.068	0.032	1986	－0.005	0.027	1936～40	0.035	0.039
50–54	0.062	0.029	1987	－0.013	0.029	1941～45	0.088	0.036
55–59	0.039	0.026	1988	－0.025	0.027	1946～50	0.100	0.035
60–64	0.021	0.025	1989	－0.022	0.026	1951～55	0.076	0.035
65–69	－0.061	0.024	1990	－0.018	0.026	1956～60	0.043	0.035
70–74	－0.175	0.024	1991	－0.010	0.028	1961～65	0.045	0.037
(Sum)	0.001		1992	－0.022	0.028	1966～70	0.083	0.040
			1993	－0.003	0.025	1971～75	0.109	0.043
			1994	－0.010	0.027	1976～80	0.095	0.046
			1995	－0.011	0.027	1981～85	0.054	0.047
			1996	－0.027	0.026	1986～90	0.008	0.047
			1997	－0.020	0.028	1991～95	－0.011	0.046
			1998	－0.020	0.030	1996～	－0.009	0.046
			1999	－0.020	0.027	(Sum)	－0.001	
			2000	－0.031	0.022			
			2001	－0.066	0.021			
			2002	－0.056	0.021			
			2003	－0.053	0.020			
			2004	－0.050	0.020			
			2005	－0.028	0.024			
			2006	－0.027	0.027			
			2007	－0.007	0.027			
			2008	0.026	0.026			
			2009	0.061	0.027			
			2010	0.065	0.027			
			2011	0.070	0.025			
			2012	0.078	0.027			
			2013	0.114	0.029			
			2014	0.121	0.031			
			(Sum)	0.001				

Note: Figures in parentheses denote standard errors in absolute value.

Source: The same as Table 9.

Table 12　At-home Fish Consumption by Age Decomposed into Age/Period/Cohort Effects, 1980-2014
Augmented BE Model in Logs
Own Price Elasticity of Fish＝－.64（.17）
Cross Price Elasticity of Meat＝.28（.16）; Cross Price Elasticity of Rice＝.02（.09）
Cross Price Elasticity of Veges＝－.14（.09）; Income Elasticity＝.41（.30）

Grand Mean Effect＝2.567（1.60）　**ABIC**＝－1153.064　（in natural logs）

Age Effects Years Old		(SE)	Period Effects Annual Year		(SE)	Cohort Effects Born in		(SE)
15–17	−0.040	0.036	1980	0.025	0.036	1906～10	0.446	0.069
20–24	−0.089	0.036	1981	0.013	0.033	1911～15	0.490	0.071
25–29	−0.156	0.038	1982	0.000	0.033	1916～20	0.499	0.072
30–34	−0.113	0.040	1983	−0.001	0.032	1921～25	0.505	0.072
35–39	−0.074	0.043	1984	−0.003	0.032	1926～30	0.502	0.070
40–44	−0.025	0.048	1985	0.000	0.033	1931～35	0.481	0.067
45–49	0.038	0.048	1986	0.004	0.033	1936～40	0.476	0.062
50–54	0.094	0.043	1987	0.000	0.033	1941～45	0.467	0.056
55–59	0.123	0.040	1988	−0.006	0.032	1946～50	0.408	0.054
60–64	0.122	0.038	1989	0.000	0.032	1951～55	0.289	0.054
65–69	0.091	0.036	1990	0.007	0.032	1956～60	0.132	0.054
70–74	0.028	0.036	1991	0.025	0.032	1961～65	−0.027	0.056
(Sum)	−0.001		1992	0.048	0.032	1966～70	−0.150	0.064
			1993	0.052	0.031	1971～75	−0.262	0.066
			1994	0.047	0.032	1976～80	−0.422	0.071
			1995	0.045	0.032	1981～85	−0.632	0.072
			1996	0.028	0.031	1986～90	−0.870	0.072
			1997	0.027	0.032	1991～95	−1.137	0.071
			1998	0.033	0.032	1996～	−1.195	0.069
			1999	0.026	0.031	(Sum)	0.000	
			2000	0.021	0.029			
			2001	0.031	0.028			
			2002	0.038	0.029			
			2003	0.017	0.028			
			2004	0.000	0.028			
			2005	−0.008	0.026			
			2006	−0.010	0.026			
			2007	−0.018	0.028			
			2008	−0.031	0.029			
			2009	−0.042	0.030			
			2010	−0.061	0.031			
			2011	−0.076	0.031			
			2012	−0.084	0.033			
			2013	−0.076	0.036			
			2014	−0.072	0.037			
			(Sum)	−0.001				

Note: Figures in parentheses denote standard errors in absolute value.

Source: The same as Table 9.

(Saegusa and Mori, 2012 ; Mori, Saegusa, and Dyck, 2012 ; Mori, Saegusa, and Tanaka, 2015 ; etc.). Saegusa named this one-step approach “augmented cohort model” following the lead of Stewart and Blisard, 2008, p.48.

Tables 9, 10, 11, and 12 provide estimates of economic elasticities on top of traditional cohort parameters--age, period, and cohort effects--for rice, bread, meat, and fish, respectively. We first introduced prices of all 5 products, rice, bread, meat, fish, and vegetables, irrespective of the product for analysis and selected the best-performing output for each product strictly in reference to **ABIC** of the model.

At first, one may notice that the structure of age/cohort effects remained basically, if not exactly, the same as the traditional cohort model without the economic variables incorporated. The augmented model has resulted in changes in period effects, as expected, for all cases of rice, bread, meat, and fish : generally flatter than the traditional model but not totally flat, implying that there remain unknown other factors which may have affected long-run changes in at-home consumption of all four products for the past some 30 years since 1980 : the case for rice is graphically presented in Figure 1. Table 13 summarizes the key economic parameters determined by the augmented model shown in the upper parts of Tables 9, 10, 11, and 12, respectively.

The own price elasticity of rice is estimated at +0.01, not significantly different from zero, whereas that for bread, meat and fish is estimated at −0.97, −0.22, and −0.64, respectively, all significantly different from zero. Meat and fish are found mutually competitive, with cross price elasticity of fish on meat is estimated at 0.22, and that of meat on fish at 0.28, both statistically different from zero at 5% level. In respect of expenditure elasticity, rice is estimated at −0.72 (SE=0.41) and fish at 0.41 (SE=0.30) and neither bread nor meat found different from zero statistically. Intuitively, estimates of demand elasticities shown in Table 13 appear to be more reasonable than those provided in linear regression models (8) and (9) in the previous section.

The cohort model, augmented with the economic variables, did not result in horizontally flat period effects, either for rice, bread, meat, or fish, as mentioned in the previous paragraph. Particularly in the case of rice, the period effects have proved distinctly negatively sloped, whereas the opposite appears to be the case with bread, i.e., the period effects are conspicuously positively sloped. Saegusa designed a cohort model, augmented with household income, prices and straight trend, the augmented cohort model-T, which will be applied to the same cohort tables, Table 2 and Appendix Tables 2, 3, and 4. When T, time trend equal to 10 for 1980, 11 for 1981, ---, and 44 for 2014, is added to the model, we obtain quite different pictures of cohort parameters, period effects, in particular, which turned out virtually horizontally flat, resulting in much narrower disparities in cohort effects between the older and newer generations. If trend has supposedly impacted a long-run decrease in rice consumption, a good part of decline could be attributed to cohort effects without T in the model, resulting in estimates of greater differences between generations. It can be observed by comparing Table 9 with Table 15. Conversely, the narrower disparities between the older and newer generations in estimated cohort effects are likely to be reflected in wider disparities between the old and the young in estimated age effects, in such a case as rice, where the individual consumption of the older people, both in terms of age and cohort, is conspicuously greater than that of the young.

Figure 1 Comparison of Simple Average with Age_Cohort Effects Compensated, and Age_Cohort and Economic Factors Compensated Period Effects, At-home Rice Consumption, 1980-2014

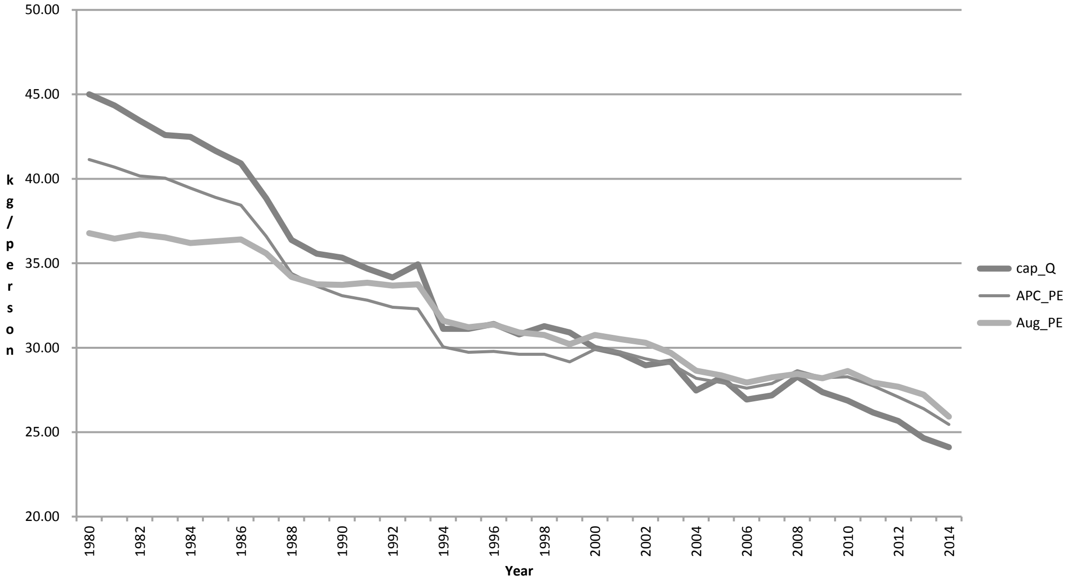

Table 13 Demand Elasticities for Rice, Bread, Meat, and Fish, Estimated by Augmented Bayesian Model

	P_rice	P_bread	P_meat	P_fish	P_veges	Exp/ae	**ABIC**
Rice	0.01	0.16	0.34	−0.30		−0.72	
	(0.12)	(0.23)	(0.23)	(0.25)		(0.41)	−1120.92
Bread	0.07	−0.97	0.13	−0.15		0.15	
	(0.09)	(0.17)	(0.17)	(0.18)		(0.30)	−1378.559
Meat		−0.11	−0.22	0.22	−0.15	0.05	
		(0.15)	(0.14)	(0.16)	(0.07)	(0.26)	−1736.379
Fish	0.02		0.28	−0.64	−0.14	0.41	
	(0.09)		(0.16)	(0.17)	(0.09)	(0.30)	−1153.064

Notes: All prices and expenditures deflated by CPI (2010 = 100);
figures in parentheses denote standard errors of estimates in absolute values.
Sources: Calculated by Mori, using the data provided in Table 2 and Appendix Tables 2, 3, and 4.

Table 14 Demand Elasticities for Rice, Bread, Meat, and Fish, Estimated by Augmented Bayesian Model, with Time Trend

	P_rice	P_bread	P_meat	P_fish	P_veges	Exp/ae	Trend	**ABIC**
Rice	−0.15	0.13	0.03	−0.32		−0.35	−0.023	
	(0.11)	(0.19)	(0.21)	(0.21)		(0.36)	(0.006)	−1134.93
Bread	0.17	−0.92	0.33	−0.15		−0.10	0.014	
	(0.09)	(0.15)	(0.16)	(0.16)		(0.28)	(0.004)	−1388.566
Meat		−0.11	−0.16	0.21	−0.15	0.00	0.004	
		(0.14)	(0.15)	(0.15)	(0.07)	(0.26)	(0.004)	−1739.796
Fish			0.17	−0.65	−0.13	0.53	−0.009	
			(0.16)	(0.16)	(0.09)	(0.27)	(0.004)	−1157.662

Notes: All prices and expenditures deflated by CPI (2010 = 100);
figures in parentheses denote standard errors of estimates in absolute values.
Sources: Calculated by Mori, using the data provided in Table 2 and Appendix Tables 2, 3, and 4.

The same appears to be the case with fish, where the older people consume distinctly more fish than the younger ones, by referring to Table 12 and Appendix Table 7.

Demand elasticities of rice, bread, meat and fish estimated by the augmented model-T are summarized in Table 14. The own price elasticities for all four products, rice, bread, meat and fish are estimated with theoretically valid sign, at −0.15, −0.92, −0.16, and −0.65, respectively. In respect to cross-relationship, rice and meat are found statistically competitive with bread, at +0.17 and +0.33, respectively, fish is competitive to meat, with the cross price elasticity of fish at +0.21, so forth. The expenditure elasticity of fish is estimated at +0.53, whereas that of rice at −0.35 and those of bread and meat are found not significantly different from zero. Trend is found statistically negative on changes in at-home consumption of both rice and fish and the opposite is the case with bread and meat.

Saegusa applied T, a straight trend, which is 10 for 1980, 11 for 1981, --, 44 for 2014, as mentioned above, without any theoretical and/or empirical background supporting it. We are not certain if it can be extrapolated to the year 2020 as 50, for example. For the sake of statistical fitness, it would be possible to apply kinky time trend, which is 10 for the first 11 years from 1980 to 1990, and then 11 for 1991, 12 for 1992, --, 34 for 2014, for example. There may be some empirical justification for this modification, since Japan's economy plunged into a long period of slow growth after the bubble burst in 1991. Tedious experiments along this line may or may not produce some useful insights into the nature of long-run changes in at-home rice consumption.

5. Demand System Analyses Using Period Effects Estimated by the Traditional A/P/C Bayesian Model

As shown clearly by Table 16, nearly 50% of daily energy intake of 2,291 kilo calories (kc) depended on rice and 10.9% on wheat, respectively and meat, eggs and milk and dairy products combined accounted for 3.9% and fish 3.8%, respectively in 1960. The dependence on rice then de-

Table 15 At-home Rice Consumption by Age Decomposed into Age/Period/Cohort Effects, 1980-2014
Augmented BE Model-T in Logs
Own Price Elasticity of Rice＝－.15(.11); Trend Effect＝－.023(.006)
Cross Price Elasticity of Bread＝.13(.23); Cross Price Elasticity of Meat＝.03(.21)
Cross Price Elasticity of Fish＝－.32(.21); Income Elasticity＝－.35(.36)

Grand Mean Effect = 7.309 (2.437)   **ABIC** = −1134.930   (in natural logs)

Age Effects Years Old		(SE)	Period Effects Annual Year		(SE)	Cohort Effects Born in		(SE)
15–17	−0.126	0.047	1980	0.012	0.044	1906～10	−0.114	0.090
20–24	−0.344	0.048	1981	0.016	0.041	1911～15	−0.065	0.092
25–29	−0.395	0.050	1982	0.030	0.041	1916～20	−0.016	0.093
30–34	−0.303	0.052	1983	0.036	0.041	1921～25	0.056	0.092
35–39	−0.150	0.057	1984	0.035	0.041	1926～30	0.136	0.090
40–44	0.007	0.064	1985	0.043	0.041	1931～35	0.210	0.084
45–49	0.095	0.064	1986	0.050	0.041	1936～40	0.254	0.078
50–54	0.139	0.057	1987	0.034	0.042	1941～45	0.255	0.072
55–59	0.198	0.052	1988	0.001	0.041	1946～50	0.219	0.070
60–64	0.263	0.050	1989	−0.003	0.041	1951～55	0.151	0.070
65–69	0.321	0.048	1990	0.005	0.041	1956～60	0.073	0.070
70–74	0.294	0.047	1991	0.012	0.042	1961～65	0.048	0.073
(Sum)	−0.001		1992	0.013	0.043	1966～70	0.045	0.080
			1993	0.014	0.044	1971～75	0.003	0.084
			1994	−0.033	0.045	1976～80	−0.086	0.090
			1995	−0.049	0.046	1981～85	−0.222	0.093
			1996	−0.042	0.046	1986～90	−0.319	0.093
			1997	−0.043	0.047	1991～95	−0.337	0.092
			1998	−0.042	0.047	1996～	−0.291	0.091
			1999	−0.048	0.046	(Sum)	0.000	
			2000	−0.029	0.044			
			2001	−0.026	0.043			
			2002	−0.021	0.043			
			2003	−0.019	0.042			
			2004	−0.029	0.042			
			2005	−0.036	0.043			
			2006	−0.034	0.044			
			2007	−0.013	0.045			
			2008	0.011	0.046			
			2009	0.013	0.046			
			2010	0.031	0.047			
			2011	0.029	0.046			
			2012	0.034	0.047			
			2013	0.034	0.049			
			2014	0.012	0.050			
			(Sum)	−0.002				

Note: Figures in parentheses denote standard errors in absolute value.

Source: Estimated by Mori.

Table 16 Changes in Energy Sources by Commodity Groups, from 1960 to 2012

(%)

	FY1960	YF1975	YF1990	YF2010	YF2012
celeals	62.81	47.31	38.63	37.69	36.82
a. rice	48.26	34.01	25.87	23.72	22.58
b. wheat	10.94	12.58	12.12	13.47	13.67
potatoes	3.56	1.55	1.92	1.82	2.03
soys	4.56	4.26	4.02	4.02	3.88
veges	3.68	3.10	3.23	2.88	3.05
fruits	1.27	2.29	2.29	2.56	2.71
meat	1.20	4.30	5.81	6.94	7.18
eggs	1.17	2.41	2.52	2.80	2.84
milk&dairy	1.57	3.49	5.53	6.19	6.46
fish	3.79	4.74	5.42	4.51	4.32
sugars	6.86	10.42	8.66	8.13	8.13
oil&fat	4.58	10.90	13.63	13.92	14.13
Total (%)	100.00	100.00	100.00	100.00	100.00
(KC/day)	2,290.6	2,518.3	2,640.1	2,446.6	2,429.6

Sources : *FBS*, various issues.

creased steadily to 34.0% in 1975, 25.9% in 1990, and 23.7% in 2010, respectively, whereas that of wheat slightly increased to 12.6% in 1975 and 13.5% in 2010[7]. The percentage of meat, eggs and milk and dairy products in total caloric intakes conspicuously increased to 10.2% in 1975, 13.9% in 1990, and 15.9% in 2010 and that of fish increased moderately to 4.7% in 1975 and 5.4% in 1990 and then slightly declined to 4.5% in 2010.

As mentioned earlier, at-home rice consumption (preparation of raw rice at home) accounts for a declining percentage of total rice supply and yet remains the most important segment of total consumption today.

Recognizing the limitations, the demand system for this analysis comprises 4 commodity groups, rice, bread, (fresh) meat, and (fresh) fish. The Almost Ideal Demand System (AIDS) model, developed by Deaton and Muellbauer (1980), is used and in this article a unique demand system approach in association with the Bayesian A/P/C analysis is also proposed in Technical Supplement.

The expenditure share equation of commodity i is expressed as below

$$w(i) = \alpha_i + \beta_i \ln(y/P) + \Sigma\gamma_{ij} \ln(p_j) \qquad (10)$$

α_i, β_i, and γ_{ij} are parameters to be estimated

$w(i)$: commodity i's share in total expenditures for all the 4 commodities

y : total expenditures for the 4 commodities

p_j : real prices of commodity j

P : Stone's price index

Based on the Slutsky equations, the restrictions below are normally imposed

Adding up : $\sum_{i=1}^{4} \alpha_i = 1,\ \sum_{i=1}^{4} \beta_i = 0,\ \sum_{i=1}^{4} \gamma_{ij} = 0$ (11)

Homogeneity Condition : $\sum_{j} \gamma_{ij} = 0$ (12)

Symmetry Assumptions : $\gamma_{ij} = \gamma_{ji}$ (13)

In order to calculate the expenditure for commodity i in year t, we use the period effect for i at t in kg, in place of simple per capita average consumption in the ordinary time-series analyses, multiplied by the average real price of the commodity i in the year, t. The consumption data we use are thus per adult consumption, with age and cohort effects accounted for (as described in the preceding sections).

We tried AIDS estimation of demand elasticities with several modifications, with all the theoretical restrictions imposed, or one of them, symmetry deleted, for example, or trend imposed on rice, etc.

Table 17 Demand Elasticities for Rice, Bread, Meat, and Fish Estimated by AIDS Model, Using Period Effects, with Age and Cohort Effects Accounted for, 1980-2014

a)

	P_Rice	P_Bread	P_Meat	P_Fish	Expend.
Rice	−0.57 (0.015)	−0.13 (0.007)	−0.15 (0.012)	−0.14 (0.017)	0.94 (0.017)
Bread	0.29 (0.010)	−1.11 (0.008)	−0.16 (0.010)	0.17 (0.011)	1.07 (0.002)
Meat	−0.12 (0.008)	−0.07 (0.004)	−0.73 (0.013)	−0.10 (0.016)	1.02 (0.001)
Fish	−0.13 (0.014)	0.09 (0.005)	−0.12 (0.020)	−0.84 (0.03)	0.99 (0.001)

b)

	P_Rice	P_Bread	P_Meat	P_Fish
Rice	−0.49	−0.19	−0.59	−0.60
Bread	−0.10	−0.72	0.20	−0.22
Meat	−0.40	−0.06	−1.16	−0.27
Fish	0.12	0.11	0.60	−0.06

Notes : All prices and expenditures deflated by CPI (2010 = 100) ;
figures in parentheses denote standard errors of estimates in absolute values.
Source : The results in a) calculated by Saegusa. Refer to Saegusa, "Technical Appendix," Mori, Saegusa, and Inaba, 2014.

Table 17 provides a few of the Marshallian elasticity matrixes worked out. Most of the AIDS models produced negative signs for own price elasticities, but many of the cross price elasticities estimated turned out negative even between meat and fish, for example. If the system of demand is properly composed, the restrictions derived from the Slutsky equations would help determining own and cross price elasticities with fewer biases. And also, if some, or all commodities covered have different time trends in slope, some measures to rectify trend effects may need to be incorporated. These tasks are left for further analyses.

Needless to mention, expenditure elasticities by commodity groups estimated are those of expenditures of the four groups covered, not household living expenditures, used in the previous sections as proxies for household incomes (W. Thompson, 2004).

7) Noodle is another important use of wheat in Japan, besides bread, but not covered by this study, due to inconsistent data preparations in *FIES*. Boiled noodle and dry noodle to be boiled at home, and also instant noodle, which is substantially higher in price are aggregated into one category, noodles, for example.

6. Findings

Rice consumption per capita at-home declined steadily from 89.1 kg in 1963, the peak year after WWII, to 34.7 kg in 1990, when the economy enjoyed the highest prosperity before the bubble burst in 1991 and plunged into a long period of slow growth and kept falling, to 24.1 kg in 2014. When the economy grows, people tend to take more energy from animal protein and fat and less from cereals. Japan's population has been aging very rapidly for some time. Households headed by those under 40 years of age accounted for 40.8%, and those by over 60 years of age 11.7% of total households in 1965. These ratios changed to 37.7% : 14.4% in 1980, 25.4% : 24.1% in 1990, and 11.4% : 45.2% in 2010, respectively. The population aging may imply a gradual fall in per capita rice consumption on the one hand, since people tend to consume less energy-intensive foods as they turn 55 or 60, for example. On the other hand, those in their 60s in the mid 1990s, for example, were born during WWII and came of age around 1960, when most people ate a lot of rice as a main source of energy and very little meat and so their eating habits are formed with rice as a central staple : in the technical jargon, their cohort effects of rice consumption should be very high, compared to those who came of age after the post-war prosperity. Thus, aging of population may not lead to a straight decline in per capita rice consumption.

In this article, we examined changes in at-home rice consumption for the past 35 years since 1980 from the age/cohort perspectives. Then we attempted to analyze the changes in period effects, with age and cohort effects accounted for, in the framework of micro-economics, with the prices of rice and other related products--bread, meat, fish, and vegetables--and household incomes as explanatory variables. The major conclusion is that a steady and drastic decline in at-home rice consumption cannot be fully explained by the demographic and economic factors included in this study and there seem to remain unidentified forces that have contributed to almost steady decreases in consumption up to the present.

References

Deaton, Angus and John Muellbauer (1980) *Economics and Consumer Behavior*, Cambridge, Cambridge University Press.

Huang, Jikun and Howarth Bouis (2001) "Structural Change in the Demand for Food in Asia: Empirical Evidence from Taiwan," *Agricultural Economics*, 26, 57–69.

Japanese Government, Bureau of Statistics, *Family Income and Expenditure Survey*, Annual Report, various issues, Tokyo.

Japanese Government, Ministry of Agriculture, Forestry and Fisheries, *Food Balance Sheet*, various issues, Tokyo.

Japanese Government, Ministry of Health, Labour and Welfare, *National Health and Nutrition Survey in Japan*, various issues, Tokyo.

Lin, B-W, J.N. Vaiyam, J. Allhouse, and J. Cromartie (2003) *Food and Agricultural Commodity Consumption in the United States: Looking Ahead to 2010*, USDA, ERS, Agricultural Economic Report No. 820.

Mason, William and Stephen Fienberg eds. (1985) *Cohort Analysis in Social Research: Beyond the Identification Problem*, New York: Springer-Verlag.

Mori, Hiroshi eds. (2001) *Cohort Analysis of Japanese Food Consumption—New and Old Generations*, Senshu University Press, Tokyo.

Mori, Hiroshi and Toshio Inaba (1997) "Estimating Individual Fresh Fruit Consumption by Age from Household Data, 1979 to 1994," *Journal of Rural Economics*, 69(3), 175–85.

Mori, H. and D.L. Clason, and J. Lillywhite (2006) "Estimating Price and Income Elasticities for Foods in the Presence of Age-Cohort Effects," *Agribusiness: an International Journal*, 22 (2), 201–17.

Mori, Hiroshi and Yoshiharu Saegusa (2010) "Cohort Effects in Food Consumption: What They Are and How They Are Formed," *Evolutionary and Institutional Economics Review*, 7(1), 43–63.<http://link.springer.com/article/10.4441.eier.7.43>

Mori, Hiroshi and Yoshiharu Saegusa (2011) "Estimating Demand Elasticities of Fresh Fruit and Fresh Vegetables, Using Augmented Cohort Model with Economic Variables," *Senshu University Economic Bulletin*, Vol. 46, No.2, 31–53 (in Japanese).

Mori, H., Y. Saegusa and J. Dyck (2012) "Estimating Demand Elasticities in a Rapidly Aging Society—The Cases of Selected Fresh Fruits in Japan," *Annual Bulletin of Social Science*, No. 46, The Institute for Social Science, Senshu University, 123–144.

Mori, H. Y. Saegusa, and T. Inaba (2014) "Incorporating Cohort Analysis into a Demand System—At-home Consumption of Apples, Mandarins and a Few Other Fruits in the Winter Season," *Senshu University Economic Bulletin*, Vol. 49, No.2, 31–53 (in Japanese).

Mori, H. Y. Saegusa, and M. Tanaka (2015) "Augmented Cohort Analysis—A Practical Way to Predict Future At-home Consumption of Selected Food Products," *Senshu University Economic Bulletin*, Vol. 49, No.3, 39–63.

Mori, Hiroshi (2015) "An Attempt to Compensate for Structural Changes in Demand by Cohort Models," *Senshu University Economic Bulletin*, Vol. 50, No.1, 95–115 (in Japanese).

Morishima, Masaru (1984) "Shifts of Demand Curve and Estimation of Food Demand by Age," *Journal of Rural Economics*, 56(2), 63–69 (in Japanese).

Nakamura, Takashi (1986) "Bayesian Cohort Models for General Cohort Tables," *Annals of the Institute of Statistical Mathematics*, 38, 353–370. <http://www.ism.ac.jp/editsec/aism/pdf/038_2_0353.pdf>

OECD (1982) *The OECD List of Social Indicators*, Paris.

Ohga, Keiji (1999) Professor at Tokyo University, Graduate School, Personal Communications, May 9, at Waseda University and June 9, at National Research Institute of Agricultural Economics, Tokyo.

Pollak, R. A and T. J. Wales (1981) "Demographic Variables in Demand Analysis," *Econometrica*, 49 (6), 1533–1551.

Prais, S.J. (1953) "The Estimation of Equivalent–Adult Scales from Family Budgets," *Economic Journal*, 63, No.25, 791–810.

Saegusa, Yoshiharu and Hiroshi Mori (2012) "Estimating Demand Elasticities by Means of Augmented Cohort Model—The Cases of Beef and Wine," *Senshu University Economic Bulletin*, Vol. 47, No. 1, 1–22 (in Japanese).

Salathe, Larry. (1979) "The Effects of Changes in Population Characteristics on U.S. Consumption of Selected Foods," *American Journal of Agricultural Economics*, 61 (5), 1036–1045.

Schrimper, R.A. (1979) "Demographic Changes and the Demand for Food: Discussion," *American Journal of Agricultural Economics*, 61 (5), 1058–60.

Stewart, Hayden and Noel Blisard (2008) "Are Younger Cohorts Demanding Less Fresh Vegetables?," *Review of Agricultural Economics*, Vol. 30, No. 1, 43–60.

Tanaka, M., H. Mori and T. Inaba (2004) "Re-estimating per Capita Individual Consumption by Age from Household Data," *Japanese Journal of Rural Economics*, Vol. 6, 20–30.

Thompson, Wyatt (2004) "Using Elasticities from an Almost Ideal Demand System? Watch out for Group Expenditure!" *American Journal of Agricultural Economics*, 86 (4), 1108–1116.

Tokoyama, Hiromi and Fumio Egaitsu (1994) "Major Categories of Changes in Food Consumption Patterns in Japan," *Oxford Agrarian Studies*, Vol. 22, No, 2, 191–202.

Yang, Y., W.J. Fu, and K.C. Land (2004) "A Methodological Comparison of Age-Period-Cohort Models: The Intrinsic Estimator and Conventional Generalized Models," *Sociological Methodology*, Vol. 34, 75–110.

Yang, Y., S. Schulhofer-Wohl, W.J. Fu, and K.C. Land (2008) "The Intrinsic Estimator for Age-Period-Cohort Analysis: What It Is and How to Use It," *American Journal of Sociology*, Vol. 113, No. 6, 1697–1736.

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Appendix Table 1　Individual At-home Rice Consumption by Age Decomposed into Age, Period, and Cohort Effects, 1980-2014, Intrinsic Estimator Model

Grand Mean Effects = 36.023 (.157)　(kg/person)

Age Efects Age yrs		(SE)
15–19	−2.699	0.36
20–24	−8.005	0.33
25–29	−9.460	0.33
30–34	−7.505	0.33
35–39	−3.540	0.33
40–44	1.373	0.33
45–49	3.939	0.33
50–54	4.451	0.33
55–59	5.354	0.33
60–64	6.221	0.33
65–69	6.723	0.34
70–74	3.150	1.16
(Sum)	−0.002	

Note: Figure in parentheses denotes standard error.

Period Effects Year		(SE)
1980	12.287	0.54
1981	11.548	0.54
1982	10.747	0.55
1983	11.352	0.55
1984	9.754	0.55
1985	9.400	0.55
1986	8.973	0.55
1987	6.457	0.55
1988	3.105	0.55
1989	2.907	0.55
1990	2.066	0.55
1991	1.625	0.55
1992	0.554	0.55
1993	1.493	0.55
1994	−2.164	0.55
1995	−2.585	0.55
1996	−2.383	0.55
1997	−2.435	0.55
1998	−2.356	0.55
1999	−2.494	0.55
2000	−1.903	0.55
2001	−2.924	0.55
2002	−3.284	0.55
2003	−3.141	0.55
2004	−4.804	0.55
2005	−4.983	0.55
2006	−6.028	0.55
2007	−6.039	0.55
2008	−4.118	0.55
2009	−5.142	0.55
2010	−5.641	0.55
2011	−6.328	0.55
2012	−7.102	0.55
2013	−7.889	0.55
2014	−8.529	0.57
(Sum)	−0.002	

Source: Estimated by Mori.

Cohort Effects Born		(SE)
1906～10	3.478	1.72
1911～15	5.274	1.06
1916～20	5.698	0.75
1921～25	6.789	0.65
1926～30	8.292	0.57
1931～35	9.775	0.52
1936～40	10.004	0.48
1941～45	7.861	0.46
1946～50	4.031	0.46
1951～55	−0.191	0.46
1956～60	−3.722	0.45
1961～65	−4.147	0.44
1966～70	−3.689	0.45
1971～75	−4.670	0.48
1976～80	−6.109	0.52
1981～85	−8.501	0.57
1986～90	−9.774	0.67
1991～95	−10.669	0.82
1996～	−10.179	1.38
(Sum)	−0.003	

Appendix Table 2 Estimates of Individual At-home Consumption of Bread by Age Groups, 1980-2014

Age/Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
15～19	14.32	14.62	14.05	13.19	13.17	12.90	13.47	13.37	13.89	13.74	13.67	13.37	14.39	14.38	14.14	13.83	13.81	13.43
20～24	11.32	12.03	11.19	10.84	10.55	10.60	10.76	10.83	11.27	11.31	11.35	11.15	11.90	11.76	11.51	11.42	11.40	11.26
25～29	11.02	11.47	10.83	10.80	10.19	10.36	10.20	10.35	10.89	10.97	11.13	11.04	11.82	11.41	11.07	11.10	11.10	11.26
30～34	11.99	12.06	11.98	11.88	11.47	11.33	10.73	10.75	11.37	11.70	11.76	12.19	11.74	11.68	12.01	11.64	12.06	12.23
35～39	11.97	11.72	12.03	12.16	11.93	11.41	11.20	10.93	11.14	11.70	11.52	11.94	11.14	11.83	12.39	11.84	12.31	12.32
40～44	11.63	11.56	11.76	11.72	11.81	10.85	11.51	10.97	11.20	11.83	11.41	11.62	11.61	12.14	12.61	11.92	12.50	12.46
45～49	10.39	11.03	10.50	10.59	10.43	10.43	10.84	10.23	10.01	10.98	10.80	11.06	10.55	11.43	12.11	11.67	11.96	11.60
50～54	9.79	10.06	9.04	9.94	9.69	9.53	9.31	8.98	8.72	10.15	9.93	10.53	9.08	10.20	11.07	10.71	11.29	11.38
55～59	9.62	9.09	9.66	10.73	9.70	9.60	9.58	8.94	8.70	10.03	9.86	10.23	10.15	10.64	10.94	10.58	11.28	11.90
60～64	9.83	10.02	10.58	11.24	10.76	10.53	10.44	9.89	10.05	10.28	10.39	10.63	11.09	11.39	11.60	11.47	11.45	11.19
65～69	9.73	10.11	10.74	11.24	11.58	11.29	11.08	11.25	10.23	10.71	11.02	11.28	11.84	12.37	12.07	11.90	11.57	11.62
70～74	8.78	9.22	9.78	10.17	10.82	10.54	10.31	10.76	9.33	9.89	10.24	10.48	11.02	11.59	11.34	11.17	10.95	11.13
75～	7.58	7.99	8.43	8.78	9.43	9.19	9.00	9.49	8.05	8.63	8.96	9.18	9.63	10.14	10.13	9.97	9.75	9.99

(kg/person)

Age/Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
15～19	13.32	13.45	13.30	11.00	15.26	16.31	16.63	16.03	14.96	14.33	13.86	14.22	14.45	15.04	14.79	13.97	13.15
20～24	11.01	11.09	11.13	11.05	12.92	13.92	14.03	13.74	13.03	12.24	11.78	11.76	12.04	13.02	12.46	11.64	11.19
25～29	10.78	10.89	10.97	12.16	12.80	14.01	13.80	13.74	13.21	12.39	11.90	11.53	11.91	13.21	12.30	11.48	11.35
30～34	12.13	12.41	12.32	12.62	14.00	14.88	14.20	14.13	14.09	14.07	13.63	13.61	13.57	13.33	12.96	13.25	13.33
35～39	12.59	12.74	12.99	12.33	14.65	15.07	14.79	14.35	14.58	15.04	14.71	15.22	14.95	13.80	13.96	14.76	14.74
40～44	12.71	13.35	12.75	12.24	14.57	14.47	15.36	14.30	14.60	15.04	14.83	15.84	15.66	14.58	15.03	15.59	15.24
45～49	12.39	12.79	12.39	12.31	14.38	13.85	15.14	14.00	14.75	15.00	14.81	15.83	15.65	14.75	15.18	15.72	15.55
50～54	11.93	12.28	12.01	12.33	14.15	13.39	14.50	13.65	15.04	15.06	14.80	15.46	15.25	14.62	14.73	15.44	15.81
55～59	11.88	12.52	11.94	10.04	14.13	13.75	14.84	13.98	15.38	15.51	15.29	15.64	15.65	15.48	15.16	15.78	16.44
60～64	11.55	12.58	12.16	12.34	14.29	14.63	15.71	14.70	15.68	16.23	16.17	16.37	16.71	17.07	16.37	16.67	17.32
65～69	11.77	12.65	12.57	12.54	14.65	15.26	15.92	15.11	15.69	16.50	16.56	16.98	17.10	17.59	17.07	17.10	17.74
70～74	11.19	11.93	12.40	12.09	14.20	14.87	14.91	14.52	14.77	15.66	15.77	16.56	16.31	16.64	16.62	16.49	17.11
75～	10.01	10.61	11.42	10.90	12.81	13.59	13.38	13.21	13.35	14.18	14.31	15.20	14.72	14.95	15.15	14.97	15.56

Note： Three youngest groups, 0～4, 5～9, and 10～14 are not provided in the table.
Sources： Calculated by Mori, using *FIES*, classified by HH age groups.

Appendix Table 3 Estimates of Individual At-home Consumption of Fresh Meats by Age Groups, 1980-2014

Age/Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
15－19	16.45	15.96	15.97	15.91	16.75	17.22	17.62	17.43	17.07	17.10	16.88	16.63	17.49	17.35	17.12	17.34	17.26	16.61
20－24	13.23	12.81	12.71	12.72	13.07	13.36	13.93	13.75	13.38	13.25	13.40	13.27	14.25	14.21	14.01	14.32	14.28	13.84
25－29	12.63	12.15	11.90	11.85	12.13	12.13	12.94	12.71	12.28	11.99	12.25	12.42	13.46	13.30	13.16	13.58	13.68	13.36
30－34	13.09	12.76	12.91	12.49	12.73	12.76	12.97	12.69	12.57	12.50	12.29	12.56	12.37	12.43	12.85	12.95	12.55	12.61
35－39	13.60	13.43	13.83	13.42	13.30	13.20	13.59	13.63	13.55	13.33	13.06	13.35	12.58	12.85	12.97	13.20	12.52	13.08
40－44	13.62	13.51	14.04	13.81	14.42	14.49	14.13	14.93	14.93	14.79	14.38	14.21	13.89	14.37	14.65	14.31	13.96	13.85
45－49	13.47	13.54	14.40	13.96	14.08	15.11	14.50	14.66	14.46	15.36	15.06	14.81	14.35	15.27	15.25	15.34	14.58	14.81
50－54	12.99	13.10	13.89	13.65	13.11	13.68	13.17	13.81	13.64	13.82	14.25	13.86	13.65	14.90	15.15	15.10	14.30	14.76
55－59	12.04	12.03	12.61	12.08	12.28	12.49	12.45	13.03	12.77	12.76	12.75	13.18	13.01	13.66	13.50	13.76	13.88	14.22
60－64	12.07	11.34	11.50	10.57	11.36	11.57	11.51	11.79	11.47	11.99	11.94	12.11	12.33	12.54	12.87	12.98	12.70	13.42
65－69	10.56	10.30	10.66	9.70	9.89	10.03	10.39	10.37	9.81	10.31	10.41	10.76	10.80	11.17	11.06	11.19	11.30	11.74
70－74	9.01	8.98	9.42	8.53	8.45	8.58	9.05	8.92	8.31	8.79	8.94	9.31	9.27	9.71	9.42	9.54	9.81	10.07
75－	7.46	7.51	7.91	7.17	7.00	7.12	7.55	7.42	6.86	7.26	7.42	7.76	7.70	8.13	7.82	7.93	8.20	8.38

(kg/person)

Age/Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
15－19	16.36	16.05	16.04	16.08	16.36	15.52	14.69	14.97	16.16	15.88	16.19	16.48	16.88	17.11	17.46	17.56	18.39
20－24	13.80	13.40	13.29	13.45	13.83	13.19	12.94	12.69	13.84	13.55	13.66	13.94	13.87	14.35	14.05	14.45	15.05
25－29	13.58	13.29	12.93	13.26	13.74	13.33	12.93	12.47	13.77	13.70	13.66	13.97	13.52	14.26	13.32	13.85	14.48
30－34	13.02	13.28	12.72	12.64	12.91	12.90	13.09	12.87	13.18	13.88	13.87	14.55	14.22	14.43	14.02	14.31	14.84
35－39	12.88	13.03	13.17	12.63	12.75	12.77	13.23	13.50	13.07	13.98	14.19	15.04	15.13	14.83	15.31	15.50	15.79
40－44	13.85	13.99	14.22	13.25	13.36	13.10	13.44	14.27	13.58	14.06	14.62	15.44	15.99	15.40	16.77	17.18	17.03
45－49	14.18	14.45	14.95	13.70	13.96	13.57	13.97	14.88	14.09	14.25	14.83	15.75	16.09	15.55	16.92	17.94	17.24
50－54	14.71	14.67	15.29	13.91	14.43	14.08	14.58	15.24	14.48	14.53	14.89	16.01	15.64	15.41	16.07	17.87	16.66
55－59	14.06	14.57	14.92	13.73	14.28	14.25	14.27	15.01	14.46	14.78	15.12	16.24	15.64	15.61	15.76	17.64	16.43
60－64	13.05	14.00	14.12	13.27	13.74	14.11	13.41	14.44	14.05	14.88	15.38	16.32	15.97	16.09	16.03	17.29	16.63
65－69	11.48	12.45	12.39	11.72	12.18	12.46	11.76	12.86	12.54	13.26	13.81	14.49	14.45	14.83	14.78	15.48	15.40
70－74	9.86	10.74	10.55	9.94	10.43	10.38	10.07	11.09	10.78	11.08	11.59	12.04	12.25	12.92	12.99	13.29	13.68
75－	8.22	8.95	8.74	8.20	8.66	8.48	8.38	9.24	8.95	9.03	9.46	9.77	10.03	10.76	10.85	11.01	11.52

Note： The same as Appendix Table 2.
Sources： The same as Appendix Table 2.

Appendix Table 4 Estimates of Individual At-home Consumption of Fresh Fish by Age Groups, 1980-2014

Age/Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
15～19	11.23	10.51	9.32	9.77	9.53	9.55	9.46	9.02	8.52	8.71	7.97	7.16	8.15	7.66	7.33	7.01	5.90	5.55
20～24	11.73	11.15	9.78	10.30	9.43	9.52	9.79	8.65	8.21	8.68	7.75	7.30	8.51	7.82	7.87	7.85	6.68	6.39
25～29	12.42	11.89	10.44	10.96	10.01	9.88	10.05	8.70	8.28	8.67	7.69	7.46	8.61	7.76	7.94	7.99	7.02	6.93
30～34	14.50	13.80	12.93	13.06	12.98	12.08	12.08	11.20	11.06	10.56	9.99	10.05	9.86	9.60	9.89	9.23	8.44	8.35
35～39	15.79	15.06	14.61	14.80	14.66	13.84	13.90	13.20	13.00	12.45	12.20	12.27	12.27	12.21	11.63	11.26	10.65	10.73
40～44	15.81	15.34	15.40	15.81	15.94	15.63	15.65	15.31	15.29	14.68	14.53	14.49	14.67	15.00	14.50	13.97	13.67	13.70
45～49	17.03	16.43	16.37	16.83	17.55	16.88	17.33	17.25	17.03	17.18	16.79	17.21	17.42	18.13	17.76	17.96	17.03	16.76
50～54	18.67	18.45	18.58	19.19	18.85	18.39	19.35	18.24	18.29	18.47	18.11	18.98	19.42	20.00	20.05	20.37	19.82	19.84
55～59	19.90	19.62	19.85	20.34	20.62	19.88	20.28	19.26	19.35	19.07	18.76	19.43	20.48	20.73	20.21	20.86	21.08	21.29
60～64	19.87	19.89	19.15	19.94	21.16	20.35	19.15	19.56	19.24	19.53	19.20	19.21	20.68	20.70	19.83	19.96	20.55	21.41
65～69	18.57	18.49	18.78	19.00	20.03	20.03	18.53	18.48	18.42	18.90	18.40	19.07	20.30	20.84	19.39	19.34	19.64	20.01
70 ～74	17.12	17.00	17.76	17.73	18.61	18.98	17.47	17.20	17.27	17.83	17.28	18.22	19.28	20.06	18.45	18.36	18.46	18.56
75～	15.46	15.35	16.18	16.10	16.83	17.28	15.93	15.57	15.69	16.22	15.69	16.68	17.60	18.44	16.92	16.85	16.87	16.85

(kg/person)

Age/Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
15～19	5.39	5.15	4.51	5.40	5.07	4.29	4.07	4.05	3.71	3.20	3.48	3.08	2.89	2.86	2.72	2.79	3.12
20～24	6.22	5.96	5.55	6.30	6.02	5.50	5.28	5.12	4.77	4.32	4.64	4.00	3.53	3.65	3.28	3.45	3.52
25～29	6.79	6.62	6.34	6.90	6.86	6.47	6.31	6.06	5.69	5.57	5.89	5.18	4.50	4.70	4.09	4.35	4.19
30～34	8.50	8.26	7.58	7.78	8.33	7.63	7.73	7.27	6.98	7.17	7.03	6.63	6.01	5.79	5.40	5.11	4.92
35～39	10.60	10.10	9.84	9.39	10.06	9.17	9.25	8.83	8.43	8.55	8.02	7.98	7.42	6.80	6.62	6.09	5.87
40～44	13.35	12.65	12.93	11.87	12.21	11.37	11.11	10.94	10.30	9.96	9.14	9.39	8.77	7.84	7.77	7.39	7.04
45～49	16.57	15.62	15.16	14.70	14.87	14.26	13.85	13.61	12.81	12.06	10.98	11.18	10.27	9.18	9.10	8.72	8.08
50～54	19.41	18.33	18.97	17.56	17.77	17.47	17.07	16.56	15.71	14.78	13.47	13.43	12.03	10.94	10.69	10.23	9.16
55～59	20.92	20.25	21.30	19.18	19.74	19.62	19.08	18.69	17.93	17.47	16.05	16.11	14.38	13.26	12.62	12.45	11.03
60～64	20.61	20.43	20.75	19.75	20.82	20.73	20.05	19.96	19.14	19.64	18.31	18.71	16.92	15.83	14.70	15.05	13.57
65～69	19.64	19.95	20.13	19.57	20.96	20.75	20.23	20.02	19.25	20.04	19.10	19.46	18.01	17.09	15.96	16.32	14.92
70～74	18.41	18.91	18.99	18.14	19.59	19.22	19.03	18.48	17.76	18.33	17.93	17.99	17.14	16.50	15.72	15.75	14.75
75～	16.79	17.31	17.38	16.42	17.77	17.39	17.34	16.67	15.99	16.38	16.23	16.13	15.57	15.10	14.54	14.41	13.64

Note： The same as Appendix Table 2.
Sources： The same as Appendix Table 2.

Appendix Table 5　At-home Bread Consumption by Age Decomposed into Age/Period/Cohort Effects, 1980-2014
Augmented BE Model-T in Logs
Own Price Elasticity of Bread＝−0.92(.15); Trend Efect＝.014(.004)
Cross Price Elasticity of Rice＝.17(.09); Cross Price Elasticity of Meat＝.33(.16)
Cross Price Elasticity of Fish＝−.15(.16); Income Elasticity＝−.10(.28)

Grand Mean Effect＝5.984(1.68)　　**ABIC**＝−1388.566　　(in natural logs)

Age Effects Years Old		(SE)
15–17	0.181	0.035
20–24	−0.041	0.035
25–29	−0.091	0.037
30–34	−0.039	0.038
35–39	−0.025	0.042
40–44	−0.017	0.047
45–49	−0.046	0.047
50–54	−0.083	0.042
55–59	−0.051	0.038
60–64	0.033	0.037
65–69	0.099	0.035
70–74	0.081	0.035
(Sum)	0.001	

Note: Figures in parentheses denote standard errors in absolute value.

Period Effects Annual Year		(SE)
1980	−0.006	0.034
1981	−0.004	0.032
1982	−0.006	0.032
1983	−0.005	0.032
1984	−0.022	0.032
1985	−0.034	0.032
1986	−0.034	0.032
1987	−0.042	0.033
1988	−0.048	0.032
1989	−0.020	0.032
1990	−0.011	0.032
1991	0.004	0.033
1992	0.003	0.033
1993	0.011	0.034
1994	0.014	0.035
1995	0.020	0.034
1996	0.031	0.036
1997	0.030	0.037
1998	0.032	0.037
1999	0.040	0.036
2000	0.024	0.035
2001	0.002	0.034
2002	0.016	0.033
2003	0.009	0.032
2004	−0.001	0.033
2005	−0.020	0.033
2006	−0.016	0.034
2007	−0.013	0.035
2008	−0.004	0.036
2009	0.018	0.036
2010	0.020	0.037
2011	0.018	0.036
2012	0.008	0.037
2013	−0.008	0.038
2014	−0.006	0.039
(Sum)	0.000	

Source: Calculated by Mori, using Saegusa's BE-T model.

Cohort Effects Born in		(SE)
1906～10	−0.374	0.062
1911～15	−0.239	0.063
1916～20	−0.174	0.064
1921～25	−0.129	0.064
1926～30	−0.099	0.062
1931～35	−0.068	0.058
1936～40	−0.002	0.054
1941～45	0.059	0.050
1946～50	0.114	0.048
1951～55	0.139	0.048
1956～60	0.149	0.048
1961～65	0.157	0.050
1966～70	0.160	0.055
1971～75	0.155	0.058
1976～80	0.131	0.062
1981～85	0.072	0.064
1986～90	0.033	0.064
1991～95	−0.024	0.063
1996～	−0.059	0.062
(Sum)	0.001	

Appendix Table 6 At-home Meat Consumption by Age Decomposed into Age/Period/Cohort Effects, 1980-2014

Augmented BE Model-T in Logs

Own Price Elasticity of Meat=−.16(.15); Trend Effect=.004(.004)

Cross Price Elasticity of Fish=.21(.15); Cross Price Elasticity of Bread=−.11(.14)

Cross Price Elasticity of Veges=−.15(.07); Income Elasticity=.003(.26)

Grand Mean Effect = 3.386(1.562) **ABIC** = −1739.796 (in natural logs)

Age Effects Years Old		(SE)
15–17	0.218	0.026
20–24	0.008	0.026
25–29	−0.047	0.027
30–34	−0.057	0.028
35–39	−0.031	0.031
40–44	0.032	0.035
45–49	0.066	0.035
50–54	0.056	0.031
55–59	0.028	0.028
60–64	0.006	0.027
65–69	−0.081	0.026
70–74	−0.198	0.026
(Sum)	0.000	

Note: Figures in parentheses denote standard errors in absolute value.

Period Effects Annual Year		(SE)
1980	0.066	0.032
1981	0.045	0.032
1982	0.038	0.033
1983	0.021	0.032
1984	0.028	0.032
1985	0.028	0.033
1986	0.025	0.033
1987	0.015	0.034
1988	0.001	0.034
1989	0.002	0.033
1990	0.002	0.034
1991	0.008	0.035
1992	−0.005	0.036
1993	0.013	0.037
1994	0.005	0.039
1995	0.001	0.040
1996	−0.019	0.040
1997	−0.015	0.040
1998	−0.019	0.041
1999	−0.022	0.040
2000	−0.036	0.038
2001	−0.073	0.037
2002	−0.066	0.036
2003	−0.068	0.035
2004	−0.069	0.035
2005	−0.050	0.036
2006	−0.054	0.037
2007	−0.037	0.038
2008	−0.009	0.038
2009	0.025	0.039
2010	0.026	0.040
2011	0.028	0.038
2012	0.034	0.038
2013	0.066	0.040
2014	0.066	0.040
(Sum)	0.001	

Source: Calculated by Mori, using Saegusa's BE-T model.

Cohort Effects Born in		(SE)
1906～10	−0.130	0.050
1911～15	−0.148	0.050
1916～20	−0.134	0.051
1921～25	−0.103	0.051
1926～30	−0.040	0.049
1931～35	0.006	0.046
1936～40	0.048	0.042
1941～45	0.097	0.039
1946～50	0.105	0.038
1951～55	0.076	0.038
1956～60	0.039	0.038
1961～65	0.036	0.040
1966～70	0.071	0.044
1971～75	0.092	0.046
1976～80	0.074	0.049
1981～85	0.028	0.051
1986～90	−0.023	0.051
1991～95	−0.046	0.051
1996～	−0.047	0.050
(Sum)	0.001	

Appendix Table 7　At-home Fish Consumption by Age Decomposed into Age/Period/Cohort Effects, 1980-2014
Augmented BE Model-T in Logs
Own Price Elasticity of Fish＝−.65(.16); Trend Effect＝−.009(.004)
Cross Price Elasticity of Meat＝.17(.16)
Cross Price Elasticity of Veges＝−.13(.09); Income Elasticity＝.53(.27)

Grand Mean Effect＝2.567(1.60)　**ABIC**＝−1157.662　(in natural logs)

Age Effects Years Old		(SE)	Period Effects Annual Year		(SE)	Cohort Effects Born in		(SE)
15–17	−0.164	0.047	1980	−0.013	0.029	1906～10	0.248	0.090
20–24	−0.191	0.047	1981	−0.021	0.028	1911～15	0.308	0.092
25–29	−0.236	0.049	1982	−0.032	0.029	1916～20	0.340	0.093
30–34	−0.169	0.051	1983	−0.031	0.028	1921～25	0.369	0.092
35–39	−0.108	0.057	1984	−0.032	0.028	1926～30	0.388	0.091
40–44	−0.036	0.063	1985	−0.028	0.029	1931～35	0.390	0.085
45–49	0.049	0.063	1986	−0.024	0.030	1936～40	0.408	0.078
50–54	0.129	0.057	1987	−0.027	0.030	1941～45	0.422	0.071
55–59	0.180	0.051	1988	−0.031	0.030	1946～50	0.385	0.070
60–64	0.201	0.049	1989	−0.024	0.029	1951～55	0.289	0.070
65–69	0.194	0.047	1990	−0.014	0.029	1956～60	0.154	0.070
70–74	0.152	0.047	1991	0.005	0.030	1961～65	0.018	0.072
(Sum)	0.001		1992	0.027	0.031	1966～70	−0.082	0.080
			1993	0.031	0.032	1971～75	−0.172	0.085
			1994	0.028	0.033	1976～80	−0.310	0.091
			1995	0.027	0.034	1981～85	−0.496	0.093
			1996	0.015	0.034	1986～90	−0.712	0.093
			1997	0.018	0.034	1991～95	−0.955	0.092
			1998	0.026	0.034	1996～	−0.993	0.090
			1999	0.023	0.033	(Sum)	−0.001	
			2000	0.022	0.032			
			2001	0.034	0.032			
			2002	0.044	0.031			
			2003	0.030	0.030			
			2004	0.019	0.030			
			2005	0.015	0.030			
			2006	0.017	0.030			
			2007	0.013	0.031			
			2008	0.005	0.032			
			2009	−0.004	0.033			
			2010	−0.019	0.034			
			2011	−0.029	0.034			
			2012	−0.034	0.034			
			2013	−0.023	0.035			
			2014	−0.013	0.037			
			(Sum)	0.000				

Note: Figures in parentheses denote standard errors in absolute value.

Source: Calculated by Mori, using Saegusa's BE-T model.

《Technical Supplements》

An Attempt to Incorporate A/P/C Model into a Demand System

(Yoshiharu Saegusa)

1. Preface

1.1 Almost Ideal Demand System(AIDS)

The data comprises 4 food groups, (fresh) fish, (fresh) meat, rice, and bread ($\ell = 1, 2, 3, 4$) and for the period of 1980–2014, 35 years ($j = 1, 2, --, n$), the same as in the foregoing text. Individual at-home consumption by 12 age groups ($i = 1, 2, --, m$), from 15–19 to 70–74 years old, by 5 year bracket is used. Let $X_\ell(j, i)$ denate per adult consumption at time j by individual household members of i years old and $P_\ell(j)$ average real price of commodity ℓ at time j. Dividing expenditure for commodity ℓ by individual of i years of age by total expenditure for the 4 food groups at time j, we obtain :

$W_\ell(j, i) = X_\ell(j, i)/S(j, i)$

where

$S(j, i) = \Sigma\ X_\ell(j, i)^* P_\ell(j)$

In one of our preceding papers (Saegusa, 2013, pp.125–144), the following equation is used in fitting AIDS to the series of expenditure shares above.

$$W_\ell(j, i) = \mu_\ell + \Sigma\ \gamma_{ik}\ LnP_k(j) + \beta_\ell Ln(S(j, i)/P_j^*) + error$$

γ_{l4} is deleted by adding the condition of homogeneity as below :

$$W_\ell(j, i) = \mu_\ell + \Sigma\ \gamma_{\ell k}\ Ln(P_k(j) + \beta_\ell Ln(S(j, i)/P_j^*) + error \qquad (1)$$

where P_j^* is the Stone price index.

In the following paper which analyzed consumption of fresh fruit in the winter season (Mori, Saegusa, and Inaba, 2014, pp.127–144), AIDS is expressed as below, by replacing $p_k(j) = LnP_k(j)$, and $z(j, i) = Ln(S(j, i)/P^*)$

$$W_\ell(j, i) = \mu_\ell + \Sigma\ \gamma_{\ell k}\ p_k(j) + \gamma_{\ell 0}\ z(j, i),\ \ell = 1, 2, 3 \qquad (2)$$

In the analyses which follow, we will depend on equation (2). First, we will add the symmetry conditions below :

$\gamma_{21} = \gamma_{12},\ \gamma_{31} = \gamma_{13},\ \gamma_{23} = \gamma_{32}$

Then, μ_ℓ and θ will be the only free parameters to estimate :

where $\theta = (\gamma_{11}, \gamma_{12}, \gamma_{13}, \gamma_{22}, \gamma_{23}, \gamma_{33}, \gamma_{10}, \gamma_{20}, \gamma_{30})'$

1.2 Setting-up Regression Models

Let z denote the nm×1 column vector of z(j, i) in the order of (1, 1), (1, 2), ---, (1, m), (2, 1), (2, 2), --, (2, m), --; likewise let W_ℓ denote the column vector of W_ℓ(j, i).

$$Y_t = \begin{pmatrix} W_1(t) \\ W_2(t) \\ W_3(t) \end{pmatrix}$$

where t = 1, 2, ----, nm : n = total number of years, m = total number of age classes.

The regression equation for AIDS based on the data classified by both number of years of observation and age groups can be expressed as below in equation (3).

$$Y_t = U_t\lambda + \varepsilon_t, \qquad t = 1, 2, ----, nm \qquad (3)$$

where

$\lambda = (\mu, \theta)'$, as $\mu = (\mu_1, \mu_2, \mu_3)'$

$\varepsilon_t \sim N(0, \phi)$, where ϕ is a 3x3 precision matrix

and matrix U_t has the structure below.

$$U_t = \begin{bmatrix} 1 & 0 & 0 & P_1(t) & P_2(t) & P_3(t) & 0 & 0 & 0 & Z(t) & 0 & 0 \\ 0 & 1 & 0 & 0 & P_1(t) & 0 & P_2(t) & P_3(t) & 0 & 0 & Z(t) & 0 \\ 0 & 0 & 1 & 0 & 0 & P_1(t) & 0 & P_2(t) & P_3(t) & 0 & 0 & Z(t) \end{bmatrix}$$

P(t), ℓ = 1, 2, 3 and Z(t), elements of U_t are defined as below.

Let X_b denote the partial matrix affected by the period effects, then

$X_b\ p_1 = P_1$, $X_b\ p_2 = P_2$, $X_b p_3 = P_3$, $X_{bz} = Z$

By replacing μ in equation (2) by $\mu_0 + X_b\beta$, we obtain a demand function containing the period effects, β as shift parameters. Then the expenditure share of commodity ℓ is expressed as below.

$$W_\ell(t) = U_t\ \lambda + X_b\ \beta + \varepsilon_t, \quad t = 1, 2, ---, n \times m \qquad (4)$$

The condition of "gradual changes between successive parameters" (Nakamura, 1986) is imposed on β, as described later.

2. Estimating AIDS, Using the Series of First Differences

2.1 Notation in Use

p_ℓ(j) represents the price series of commodity ℓ, j = 1, 2, ---, n

$\triangle p_\ell(j) = p_\ell(j+1) - p_\ell(j)$, j = 1, 2, ----, n–1

$\triangle p_\ell$ is a column vector of $\triangle p_\ell$(j)

z_ℓ(j, i) represents the expenditure series for commodity ℓ by i^{th} age group at year j, j = 1, 2, ---, n

$\triangle z_\ell(j, i) = z_\ell(j+1, i) - z_\ell(j, i)$, j = 1, 2, ----, n–1

$\triangle z_\ell$ represents (n–1)m × 1 column vector of $\triangle_\ell z$ (j, i) compiled in the order, (1, 1), (1, 2), --, (1, m) ; (2, 2), ----, (2, m) ; ----

In the same fashion, the series of expenditure share for commodity ℓ are compiled and let define $\triangle W_\ell$ as a column vector of $\triangle W_\ell$(j, i).

D : primary difference matrix of (n–1) × n

D(i, i) = − 1, D(i, i + 1) = 1, i = 1, 2, ----, n–1

D^* is expressed as $D \otimes I$.

where I is a unit matrix of m × m.

$\triangle p = Dp$, $\triangle W = D^* W$

X_b in equation (4) can be converted into X_b^*.

2.2 Regression Models, Using First Difference Series

Period Effects :

First, let β_j denote the element of period effects of commodity(ℓ)

$$\beta_j = \begin{pmatrix} \beta_{j1} \\ \beta_{j2} \\ \beta_{j3} \end{pmatrix}$$

Let the differences of β_j, $\triangle\beta$(j), j = 1, 2, ---, n–1 expressed as follows :

$$\triangle\beta(j) = \begin{pmatrix} \beta_{j,1} - \beta_{j-1,1} \\ \beta_{j,2} - \beta_{j-1,2} \\ \beta_{j,3} - \beta_{j-1,3} \end{pmatrix}$$

and then, $\triangle\beta$ represents the vector of $\triangle\beta$(j) compiled in the following manner ;

$\triangle\beta = (\triangle\beta(1), \text{------}, \triangle\beta(n-1))$

with$\triangle\beta$ becoming a vector of 3(n–1) × 1. In the analysis to follow, we set G = 3(n–1).

Regression Model of Difference Series

If Y_t represents a matrix below,

$$Y_t = \begin{pmatrix} \triangle W_1(t) \\ \triangle W_2(t) \\ \triangle W_3(t) \end{pmatrix}$$

Y_t can be expressed as below :

$$Yt = U^*\lambda + V\triangle\beta + \varepsilon(t),\ t = 1.2, \text{---},\ (n\text{–}i) \times m \qquad (5)$$

where

$$U^* = \begin{bmatrix} \triangle P_1(t), \triangle P_2(t), \triangle P_3(t) & 0 & 0 & 0 & \triangle Z(t) & 0 & 0 \\ 0 & \triangle P_1(t) & 0 & \triangle P_2(t), \triangle P_3(t) & 0 & 0 & \triangle Z(t) & 0 \\ 0 & 0 & \triangle P_1(t) & 0 & \triangle P_2(t), \triangle P_3(t) & 0 & 0 & \triangle Z(t) \end{bmatrix}$$

where

$\triangle P_\ell = D^* P$, ℓ = 1,2,3 ; $\triangle Z = D^* Z$

$\lambda = (\mu, \gamma_{11}, \gamma_{12}, \gamma_{13}, \gamma_{22}, \gamma_{23}, \gamma_{33}, \gamma_{10}, \gamma_{20}, \gamma_{30})'$

γ_{11}, γ_{22} and γ_{33} are own price elasticities of each commodity and γ_{10}, γ_{20} and γ_{30} refer to the parameters which show expenditure coefficients.

V is a matrix which possesses the structure below :

$$V = \begin{pmatrix} V_1(t) \\ V_2(t) \\ V_3(t) \end{pmatrix}$$

where V_1, V_2, and V_3 are matrices of dummy variables of $(n-1)m \times G$, respectively.

For example, V_1 for commodity (1) has the structure below :

$$\begin{bmatrix} I & 0 & 0 \text{-----} 0 & & \\ & & & & \\ 0 & 0 & I \text{-----} 0 & & \\ & & \ddots & & \\ & & & I & 0 \quad 0 \end{bmatrix}$$

$I = (1, 1, ---, 1)'$, a column vector of $m \times 1$ and $V_1(t)$ is the t^{th} row vector of matrix V_1.

In estimating model (5) in the Bayesian way, we set up the prior distribution of parameter, $\triangle\beta$ as follows :

$$Q\triangle\beta \sim N(0, I \otimes \psi^{-1})$$

where I is a unit matrix of $(n-1)(n-1)$, and $Q = I \otimes io$, where io is a column vector of 3×1 and Ψ is a dispersion matrix of 3×3.

$\triangle\beta(j)$, $J = 1, 2, ---, (n-1)$ are thus distributed mutually independent from each other over time, according to $N(0, \Phi^{-1})$.

Summing up, our regression model based on the difference series can be expressed as follows :

Equation (5) is rewritten as (6), assuming $X_t = (U^*, V)$

$$Y_t = X_t\,\alpha + \varepsilon_t \qquad (6)$$

where

$$\alpha = (\lambda, \triangle\beta)$$

$$R = (0, Q)$$

then, the prior distribution of α in model (6) is expressed as follows,

$R\,\alpha \sim N(0, I \otimes \Psi^{-1})$, with the error term : $\varepsilon_t \sim N(0, \Phi)$

In estimating α in equation (6) and Ψ and Φ, hyper-parameters, we depend on the Gibbs sampler which is often used in Bayesian data analysis (Gelman et al., 2004).

Bayesian Estimation by Means of the Gibbs Sampler

Samplings of α, Φ and Ψ are performed in accordance to the following posterior distribution, i.e., each distribution is drawn with vague prior given to Φ and Ψ.

$$\alpha \mid \Phi, \Psi, Y \sim N(\hat{\alpha}, V) \qquad (7.1)$$

where

$\hat{\alpha} = A(\Sigma_t \quad X_t' \quad \Phi Y)$
$A = (\Sigma_t \quad Xt' \quad \Phi X_t + R' \quad (I \otimes \Psi) R)$
$\Phi \mid \alpha, Y \sim W(\gamma_1, S_1)$ (7.2)
where
$\gamma_1 = (n-1)m-3$
$S_1 = (\Sigma_t (Y_t - X_t \hat{\alpha})(Y_t - X_t \hat{\alpha})'$
$W(\gamma_1, S_1)$ stands for the Wishart distribution of S_1, where the degree of freedom is γ_1 and the scale matrix is S_1.

$\Psi \mid \alpha, Y \sim W(\gamma_2, S_2)$ (7.3)
where
$\gamma_2 = (n-1)+1$
$S_1 = \Sigma \triangle\beta_j \triangle\beta_j'$
$W(\gamma_2, S_2)$ stands for the Wishart distribution of S_2, where the degree of freedom is γ_2 and the scale matrix is S_2.

Actual Steps :
Step 1 : Assign initial values to Φ ; Step 2 : Generate α from the distribution in (7.1) ; Step 3 : Substitute α for the distribution (7.2) to generate Φ ; Step 4 : Substitute Φ for the distribution (7.3) to generate Ψ, and then come back to Step 2. Repeat these operations N times to generate N sets of samples of (α, Φ, Ψ) to determine (α, Φ, Ψ) by averaging them.

3. Results of the Bayesian Estimation.

We can obtain demand elasticities for individual commodities by converting the estimates of α derived from the Gibbs sampler (which was repeated 1000 times for this analysis). For example, the expenditure elasticity of commodity (ℓ), E(ℓ) can be obtained by converting γ_{jo} by $E(\ell j) = (\gamma_{jo} + W_\ell)/Wj$: $\ell = 1, 2, 3, 4$, where W_ℓ denotes average expenditure share by commodity (ℓ) : 0.307, 0.328, 0.239, and 0,126 for fish, meat, rice, and bread, respectively.
The demand elasticities, own and cross price elasticities and expenditure elasticities for the 4 commodity groups estimated by the Gibbs sampler are provided in Table I, below.

In Table II, elasticities estimated based on the series of first differences, i.e., ignoring trend elements in the period effects by assuming $\triangle\beta = 0$ in model (7.3) above.

Final Notes
Readers are advised to refer to the author's previous papers, 2013 and 2014, for mathematical details.

Table I Demand Elasticities for Fish, Meat, Rice, and Bread Estimated

1st Group (fish) :	3rd Group (rice) :
E_{11} = –.5400 (.0150)	E_{31} = –.3110 (.0108)
E_{12} = –.2645 (.0810)	E_{32} = –.1619 (.0445)
E_{13} = –.2127 (.0116)	E_{33} = –.6179 (.0294)
E_{14} = –.0553 (.0975)	E_{34} = .0667 (.0675)
Exp_1 = 1.0724 (.0102)	Exp_3 = 1.2487 (.0343)
2nd Group (meat)	4th Group (bread) :
E_{21} = –.2009 (.0689)	E_{41} = .0240 (.2591)
E_{22} = –.7319 (.0300)	E_{42} = .0835 (.0628)
E_{23} = –.0398 (.0437)	E_{43} = .2446 (.0172)
E_{24} = –.0019 (.0159)	E_{44} = − 1.0205 (.0791)
Exp_2 = .9214 (.0122)	Exp_4 = .5542 (.0585)

Notes : E_{ij} stands for elasticity of jth price on demand of ith goods ;
Exp $_\ell$ stands for elasticity of expenditure for the 4 groups on demand for the ℓth goods ; Figures in parentheses denote standard errors.

Table II Demand Elasticities for Fish, Meat, Rice, and Bread Estimated, Using Series of Differences, i.e., Trend Ignored

1st Group (fish) :	3rd Group (rice) :
E_{11} = –.7556 (.0117)	E_{31} = –.2418 (.0115)
E_{12} = –.1242 (.0060)	E_{32} = –.3956 (.0189)
E_{13} = –.1694 (.0081)	E_{33} = –.4672 (.0254)
E_{14} = –.0147 (.0007)	E_{34} = .0847 (.0041)
Exp_1 = 1.0640 (.0032)	Exp_3 = 1.1968 (.0095)
2nd Group (meat)	4th Group (bread) :
E_{21} = –.0751 (.0037)	E_{41} = .0908 (.0044)
E_{22} = –.6329 (.0175)	E_{42} = –.1441 (.0069)
E_{23} = –.2250 (.0107)	E_{43} = .3624 (.0173)
E_{24} = –.0933 (.0045)	E_{44} = –.9839 (.0008)
Exp_2 = .9302 (.0034)	Exp_4 = .6612 (.0167)

Notes : E_{ij} stands for elasticity of jth price on demand of ith goods ;
Exp $_\ell$ stands for elasticity of expenditure for the 4 groups on demand for the ℓth goods ; Figures in parentheses denote standard errors.

References

Gelman, A., J.B. Carlin, H.S. Stern, and D.B. Rubin (2004) *Bayesian Data Analysis*, Second Edition, New York, Chapman & Hall/CRC.

Saegusa, Y. and H. Mori (2013) “An Attempt to Incorporate Cohort Variables into a Demand System,” *Economic Bulletin of Senshu University*, 48 (2), 125–144 (in Japanese).

Mori, H., Y. Saegusa, and T. Inaba (2014) ”Incorporating Cohort Analysis into a Demand System,” Technical Appendix, *Economic Bulletin of Senshu University*, 49 (2), 137–144 (in Japanese).